THE

THUNDER-STORM

H. M. FRIGATE "FISGARD," PROTECTED BY HARRIS'S LIGHTNING CONDUCTORS FROM A SEVERE STROKE OF LIGHTNING, SEPTEMBER 26, 1846. See p. 244.

THE
THUNDER-STORM;

OR,

An Account

OF

THE NATURE, PROPERTIES, DANGERS, AND USES OF LIGHTNING,

IN VARIOUS PARTS OF THE WORLD.

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THE THUNDER-STORM.

CHAPTER I.

INTRODUCTION — GENERAL DESCRIPTION OF A THUNDER-STORM — THUNDER-STORMS IN MOUNTAINOUS REGIONS—IN THE PYRENEES—IN THE ALPS—TRAVELLERS OVERTAKEN BY A STORM—THUNDER-STORMS IN SOUTH AFRICA—THEIR SUDDENNESS AND SHORT DURATION—BEHAVIOUR OF ANIMALS—LOUDNESS OF THE THUNDER IN AUSTRALIA —A THUNDER-STORM IN THE TROPICS—IN THE MOUNTAINOUS REGION OF CEYLON—IN AMERICA — PHENOMENA OF THUNDER-STORMS BELOW THE OBSERVER—APPEARANCES OF THE UPPER SURFACE OF THUNDER-CLOUD — NATURAL LIMIT OF THUNDER-STORMS.

THERE is, perhaps, nothing in the whole natural world more calculated to impress us with a sense of the majesty and power of the Creator, than the phenomena of a thunder-storm. The regularly recurring events of nature—the change of seasons,

the starry heavens by night, and the variety and beauty of the clouds by day,—the winds, the showers, the dew, the frost and the snow,—such events and objects seem to be so much in the ordinary course of things, that they cease to occupy our daily thoughts and attention. But who can close his eyes to the lightning's dazzling flash, or his ears to the mighty voice of the thunder? who does not feel anxious, when the rain descends in torrents from the thunder-cloud, or the hail pours down with destructive violence? At such times (which, happily, in our climate, are not frequent,) we feel, as it were, overcome with a sense of our own weakness and littleness, and participate in that dread which the inspired Psalmist imputes to the elements themselves.

"The waters saw thee, O God, the waters saw thee; they were afraid: the depths also were troubled.

"The clouds poured out water: the skies sent out a sound: thine arrows also went abroad.

"The voice of thy thunder was in the heaven: the lightnings lightened the world: the earth trembled and shook." Psalm lxxvii. 16—18.

Most persons are acquainted with the first

appearance of a thunder-storm. It is generally preceded by an oppressive heat of the atmosphere, and an awful stillness, with little or no wind. But soon the clear and serene sky is obscured by low and dense clouds of irregular shapes, and the wind comes in fitful gusts to spread them over the heavens: other clouds, more thick and obscure, follow these, and they are all agitated with various motions. While some are moving about in one direction, others below them are driven in an opposite course. At the same time may generally be observed one dense cloud, which increases rapidly in size, and rises into the higher regions of the air. Its lower surface is black and nearly level, but the upper is finely arched and well defined. This cloud is increased by others, which pile themselves one over another; all are arched the same way, and they continue to unite, to swell, and to extend their arches. The smaller clouds are attracted by this large one, and serve to increase its dimensions; but sometimes the large thunder-cloud does not gather up the smaller ones, but continues to increase rapidly in size, presenting towards the earth a ragged surface, which swells into large projecting masses; in other cases one whole side

of the cloud inclines towards the earth. At last it is seen to darken fearfully; flashes of blue light dart with inconceivable rapidity from one part to another, and after a few seconds the rumbling noise of distant thunder is heard. The sky becomes yet more obscure, the lightning more frequent and vivid, the thunder more loud, and following the lightning at a shorter interval. A solemn gloom is spread over the face of nature; the husbandman quits the fields, the fisherman his nets,—birds are no longer on the wing; cattle run about in wild dismay, or crowd for shelter from the impending danger. Man himself partakes of the general dread, and sits at home in the midst of his silent and anxious family. The storm is now at its height; rain or hail descends heavily; the accumulated electricity of the clouds strikes towards the earth, shivering the lofty tower or the mighty oak in its passage. These tremendous phenomena often make the circuit of the whole horizon, till at length the thunder-clouds becoming exhausted, get less and less dense, and finally break up altogether, showing a clear, smiling sky. All nature is refreshed,—the earth is no longer parched with thirst,—the vegetable world looks

bright and green and glittering,—the birds unite in a chorus of love and gratitude,—the cattle view the refreshing scene with complacent gaze, and man resumes his occupations, breathing a cooler and more refreshing air, and presenting the thank-offering of a grateful heart.

The thunder-storms of our own country are much less violent and of shorter duration than those which occur in continents and in the warmer regions of the earth. In mountainous countries they are very frequent, and often continue to rage during three or four days. In the vicinity of the central or highest range of the Pyrenees, they are most common during the spring and autumn, although few weeks throughout the year pass over in which they do not take place. Their duration extends to the third or fourth day from their commencement, and the peasants look forward to their termination at the end of that period with confidence, and form their plans as if the circumstance were a certainty; should a storm endure for a week, it is regarded as an extraordinary event.

A few years ago, however, a storm of unwonted violence and duration visited the Pyrenees. During

the first three or four days it was almost disregarded by the peasantry; they thought that a limited period was assigned for this warring of the elements, and never imagined the sufferings to which they would be subjected, should the storm be unusually lengthened. Accordingly, they adopted no precautionary measures; they collected no provisions; they did not conceive it necessary to withdraw the shepherds and their flocks from the mountains, and they felt no uneasiness as to their safety. But the fourth day passed; then the week; and still there was no abatement in the violence of the storm. "You can have no idea of its awfulness," said an inhabitant to Mr. Murray; "it seemed as if the mountains which surrounded our valley were fighting with each other, and their weapons the thunders and the lightnings. The incessant peals hurled from one summit to another, rolled back again with more stunning crashings; the lightnings played around our cottages, and during the darkness of the night illuminated the mountain tops; those fantastic-looking peaks every instant appeared shrouded in a blaze of light; while the rain descended in torrents, which no cottage roof could resist, and which threatened to sweep our

dwellings from their foundations, and wash us into the river, whose swollen waters, rising far above the limits of their highest floods, were already robbing us of our property. Our thoughts were at first directed to the danger of the shepherds and their flocks, but to them it was impossible to render assistance; the strongest man amongst us could not have braved the hurricane for an hour; so we were obliged to leave them to their fate, and bethink us of our own.

"Weeks succeeded weeks, and still the terrible scene was the same. There was no abatement in the thunderings, no interval in the lightnings, nor cessation in the rains. We gave ourselves up for lost, and believed that 'the end of all things was at hand.' It became apparent that death by famine, or perishing in the waters which raged around us, was the fate which shortly awaited all of us. Silent, stupified sorrow overwhelmed us, and our feelings were fast drying up; when in the end of the sixth week peace again reigned in the valley, and the clouds cleared away. The change which the first knowledge of the fact wrought upon our despairing minds may be conceived, but cannot be described."

It appears that the shepherds in the mountains outlived this storm; but the greater part of their cattle and sheep had perished. At the time of Mr. Murray's visit the traces of the storm were fearful to behold. "The village of St. Lary, situated in the centre of a beautiful basin, surrounded by fertile fields and rich meadows, of which each family had its own little portion, was one of the most contented and happy in the whole district, until this fearful storm took place. The swollen river, whose channel through the upper part of the valley had become nearly choked up by immense quantities of débris, and the enormous rocks which each mountain stream, nourished by the rains into a mighty torrrent, had swept from its steeps, and torn from precipices, having at last acquired sufficient force to overcome all the barriers which obstructed its progress through the contracted defiles of Plan and Aragnouet, dashing into its resistless flood, the natural bulwarks which for ages had stemmed its most rebellious currents, burst from the gorge of St. Lary, and, teeming with the spoils of its destructive course, spread its abundant harvest over the defenceless valley. The first burst of its pent-up wrath was wreaked

upon the commune of St. Lary. The inhabitants were driven from their village, the greater part of which was buried beneath the ruins of the upper valleys, and their smiling fields, their verdant meadows,—their little all was by this fell swoop of desolation for ever lost to them."

In another part, "the sad aspect of the scene was greatly enhanced by the solitary patches of productive land, which, saved by the current's being turned aside by a hedgerow or clump of trees, yielded its wonted returns, surrounded by barrenness and sterility."

A thunder-storm among the glaciers of the Alps, is also marked with fearful sublimity. From the windows of the little inn which commands a view of the glacier of the Mer de Glace, Professor Forbes watched with admiration the whole scenery of the glacier, lit up by the explosive lightnings which followed for some hours with little intermission, whilst the frail building seemed to rock under the fury of the gale, and vibrate to every peal of thunder. Each tiny torrent now gave tongue increasingly, until the fitful roar became a steady din, with now and then a crash arising from the discharge of stones hurried along

by the flood, or an avalanche prematurely torn from the glacier of the Mont Blanc.

But a storm witnessed from such a shelter as this, however mean, has few terrors, compared with that which overtakes the unsheltered traveller, while toiling among the precipices, the rough ice, and the treacherous snows of these sublime regions. In his descent from the summit of Mont Blanc, Mr. Auldjo encountered a thunder-storm. He and his guides were toiling through the snow, now softened by heavy showers of sleet, when tremendous flashes of lightning burst upon them; hail beat down with great force, the shower being thick and the stones of very large size. "I threw myself on the rock," says Mr. Auldjo, "and was covered with a sheet hastily unpacked; under which, notwithstanding the beating of the hail, and the wet uncomfortable state of my clothes, and the thunder above, I almost immediately fell asleep, and continued so about a quarter of an hour, when I was startled by a dreadful clap of thunder right over me. I attempted to rise, but could not disentangle myself from the sheet; the weight of the hail which had fallen upon it, and the awkward and dan-

gerous position in which I was placed on the rock, rendered me incapable of extricating myself without assistance. I called to the guides, but none heard me; they had dispersed over the rock in search of shelter, and no voice answering mine, I became greatly alarmed. The storm began to abate, and after having lasted twenty-five minutes, entirely ceased. I was soon extricated from my unpleasant situation; and as it appeared likely to continue fine, we agreed to start off instantly." After proceeding some way, they unfortunately missed the route, and became entangled in the crevices of the glacier. "To add to our misfortune, the storm recommenced with greater violence than before; the hailstones, large and sharp, driven with force by the wind, inflicted great pain on the face; we were exposed to it, standing on a narrow ledge overhanging an abyss. In this situation we awaited for a short time the return of two guides, sent to explore the crevices and banks around us, in an endeavour to discover the route of our ascent, but with very little hope of success; indeed, it was greatly feared that we should have to remain where we were for that night. Tremendous gusts of wind now burst upon us, and

the storm increasing every instant, compelled us to seek some place in the glacier in which we could obtain shelter. Following the footmarks of the guides who had gone forward, we succeeded in finding a recess, formed by the projection of a part of the glacier over a narrow ledge in the side of a deep crevice. Along this we moved with great care, and had just space to stand in a bending posture, and in a row.* I was wet through, and suffered excruciating torture from the cold and the position I was obliged to remain in. The storm raged with most awful fury; the gusts of wind, and pelting showers of hail, accompanied by most vivid lightning, alternating with a perfect calm, were enough to appal the bravest of the party." After waiting some time in this situation, they heard in one of those moments of calm, the loud halloo of one of the exploring guides who had found the route. Our traveller was so benumbed with cold that he could not keep himself from falling. Supported by one of the guides, he proceeded along the narrow ledge; "the lightning flashed every moment, immediately fol-

* See Frontispiece to this Chapter.

lowed or rather accompanied by claps of thunder, showing its proximity to us; and the loud peal rolling among the mountains and glaciers, reverberated with most terrific grandeur, shaking the broken masses of the latter in such a manner, that we dreaded, at every explosion, to be hurled into the deep crevice, or crushed by the fall of some part of the glacier."

In order to get to a lower level, it was necessary to cut steps in the perpendicular wall of cliff down which the guides descended; but as our traveller had nearly lost all feeling from the effects of the cold, he was let down by means of a rope. "At the very moment that I was rocking in the air, a flash of lightning penetrated into the abyss, and showed all the horrors of my situation; while the crash of the thunder seemed to tear the glacier down upon me. I was drawn on to the neck of ice, and sat down until the other guides had descended. . . . . All suffered dreadfully from the cold, but with a solicitude for which I shall ever be deeply grateful, they still attended me in the kindest manner. They desired me to stand up, and forming a circle, in the centre of which I stood, closed round me. In a few minutes, the

warmth of their bodies extended itself to mine, and I felt much relieved; they then took off their coats, covering me with them, and each in turn put my hands into his bosom, while another lay on my feet." In this way our traveller was soon sufficiently revived to be able to proceed and escape from the dangers of these terrible scenes, convinced, it is hoped, that a higher motive than idle curiosity, or the equally idle boast of having ascended a high mountain, is necessary, before exposing the lives of so many human beings to danger.

With far greater interest and sympathy do we read of the accidents which befall those travellers who are engaged in some good and useful mission: such a traveller was Mr. Burchell, who some years ago undertook a journey into the interior of Southern Africa, for the purpose of inquiring into the condition of the natives, with a view to its amelioration. In the wide plains of this desolate region, thunder-storms are remarkable for their suddenness and short duration. Mr. Burchell notices one of these storms, which occurred in the middle of September. He says, "The lightning began to flash, and the most

tremendous peals of thunder burst over our heads. In an instant, without perhaps more than one minute's notice, a black cloud, which had formed suddenly, emptied its contents upon us, pouring down like a torrent, and drenching every thing with water. The parched earth became, in the short time of five minutes, covered with ponds. The rain ceased as suddenly as it came on; leaving me both startled and surprised at this specimen of an African thunder-shower. We passed all at once from the deluged to the arid and dusty ground; the distance of thirty or forty yards being all that intervened between these extremes. Mention had often been made to me, while in Cape Town, of the heavy thunder-showers of the interior; but their sudden violence far exceeded all that I had imagined." Some days later he describes another of these sudden storms, accompanied with heavy rain and hail, and the most tremendous peals of thunder. "One explosion, in particular, seemed to have taken place within 200 yards of us: it sounded like the simultaneous firing of a dozen cannons, the effect of which was even increased by the sound being reiterated in echoes several times repeated, rolling through the

mountains. The wind increased to a furious hurricane; and dust, sticks, and fine gravel filled the air. This storm lasted but a quarter of an hour, and was immediately succeeded by a dead calm and a cloudless sky. The thermometer, before the commencement of the rain and thunder, stood at 79½°; during its continuance it fell to 64°; and on the termination rose again to 74°. The weather remained undisturbed and pleasant for three hours; but at sunset the hurricane returned with redoubled fury. Nothing could exceed the violence of the thunder; and the vivid glare of the lightning often blinded us for a whole minute. The rain poured down as though it would wash us out of the valley; and the wind blew with a force that was near overturning the waggons. This second tempest lasted half an hour, after which the weather continued calm and quiet the whole night."

On another occasion a thunder-storm overtook this interesting traveller at nightfall, in the midst of an open plain; and as the bleak and exposed situation of the party made it difficult to restrain the oxen from straying away in the night, they placed the waggons in a circle, connected them to-

TRAVELLING IN SOUTHERN AFRICA.
(*The small mounds are ant-hills.*)

gether with drag-ropes, to which, as well as to the wheels, the cattle were made fast. "Thunder-clouds collected in every quarter, and the night became excessively dark; until some black, formidable and massy clouds, which seemed to have the solidity of rocks, burst open all at once, and, with very little thunder, emitted every instant the most vivid flashes of lightning; which, although they rendered for the moment every object as light and visible as by day, left us in the intervals blinded by impenetrable darkness. In addition to this, torrents of the heaviest rain poured down upon us, and if it did not throw us, as it did our cattle, into confusion, it impeded, however, the work which was necessary to be done, and left us supperless, through the difficulty of keeping up a fire for cooking.

"Such nights, I already knew, by dear-bought experience, favour the prowling lion, and seem to give him a spirit of daringness which he seldom evinces at other times. Taking advantage of the disorder and confusion into which the other animals are thrown by the conflicting elements, which make no impression upon him, he appears to advance upon them with less caution than usual.

This, at least, was now found to be the case; for at a little after nine, while all of us were lying in the waggons, the dogs commenced barking and howling; the whole of the oxen suddenly made efforts to get loose, and began to express that peculiar uneasiness which, in a very intelligible manner, told us that a lion was not far off. There is probably something in the smell of this beast quite different from that of others, by which, at a great distance, especially if to windward, his prey perceives his approach, and are warned to escape their danger by instant flight. It was this natural or instinctive propensity to fly, which occasioned our oxen to struggle and endeavour to get loose; but fortunately for them, the strength of the leather halters prevented their doing this. Yet their efforts to disengage themselves were so violent, that my waggon was in great risk of being overturned; and for some time it was unsafe to remain in it. A fire is generally sufficient to hold the lion at a distance; but ours was extinguished by the rain; on which account he pressed closer upon us. Fortunately, some muskets fired at random, or aimed only by guess, had the effect not only of keeping him off, but of quieting, in a great degree, the

restlessness of the cattle. The Hottentots say, that the oxen have sagacity enough to know that the discharge of muskets, under such circumstances, is for the purpose of driving away their dreaded enemy; and whatever may be the notions of these poor animals on the subject, such is certainly the effect commonly produced on them. Perhaps it is that a certain instinct they may possess enables them to discover that the beast does actually retreat when muskets are fired off. We could discover, from an unusual and peculiar barking of the dogs, that he continued prowling round us till midnight; but his fears to encounter man were the only obstacle to prevent his carrying off his prey; and finding it thus too strongly protected, he at last withdrew. All then became quiet, and we again lay ourselves down to rest till morning." The next day the weather was fine, but very hot; and the moisture of the air from the storm caused a great sensation of lassitude, which rendered travelling very fatiguing.

In the following March the same traveller notices a shower of rain and hail so violent, that his horse refused to face it; the party was therefore obliged to halt, and turn their backs to the storm.

"The loudest claps of thunder burst over our heads, and followed the flashes of lightning without any perceptible interval of time. I could not discover in our Bushmen any symptoms of fear, though nothing could be more awful than the thunder, which seemed close above us, and exploded with a violence almost sufficient to destroy the hearing."

The extreme loudness and violence of the thunder which excited the surprise of the traveller last quoted, has also been noticed by some of the explorers of Australia. Captain Grey, in an excursion up Prince Regent's river, encountered a storm in the more contracted channel of the river. "The pealing echoes of the thunder, as they bounded from height to height, and from cliff to cliff, were awfully magnificent; whilst the rugged mountains which had just before looked golden in the bright light of the setting sun, were now shrouded in gloomy mists, and capped with dark clouds, from which issued incessant and dazzling flashes of lightning."

Mr. Bennett, also, who was travelling during the summer season (December) in New South Wales, on an excursion to the but little known

country about the Tumat river, was overtaken by some heavy clouds which had collected from the westward; they poured down a deluge of rain, accompanied by violent peals of thunder and vivid lightning: "the electric fluid burst with such crashing sounds, that I expected to see the trees shattered in ten thousand pieces by my side."

But it is within the tropics that the phenomena of a thunder-storm are observed in all their sublimity. Previous to a change of monsoon in India, vast masses of cloud rise from the Indian ocean, and advance towards the north-east, gathering and thickening as they approach the land. "After some threatening days the sky assumes a troubled appearance in the mornings, and the monsoon in general sets in during the night. It is attended with such a thunder-storm as can scarcely be imagined by those who have only seen that phenomenon in a temperate climate. It generally begins with violent blasts of wind, which are succeeded by floods of rain. For some hours lightning is seen almost without intermission: sometimes it only illuminates the sky, and shows the clouds near the horizon; at others, it discovers the distant hills, and again leaves all in darkness, when in an instant it re-

appears in vivid and successive flashes, and exhibits the nearest objects in all the brightness of day. During all this time the distant thunder never ceases to roll, and is only silenced by some nearer peal, which bursts on the ear with such a sudden and tremendous crash as can scarcely fail to strike the most insensible heart with awe. At length the thunder ceases, and nothing is heard but the continual pouring of the rain and the rushing of the rising streams. The next day presents a gloomy spectacle; the rain still descends in torrents, and scarcely allows a view of the blackened fields; the rivers are swollen and discoloured, and sweep down along with them the hedges, the huts, and the remains of the cultivation carried on during the dry season, in their beds.

" This lasts for some days, after which the sky clears, and discovers the face of nature changed, as if by enchantment. Before the storm, the fields were parched up, and except in the beds of the rivers scarce a blade of vegetation was to be seen: the clearness of the sky was not interrupted by a single cloud, but the atmosphere was loaded with dust, which was sufficient to render distant objects dim, as in a mist, and to make the sun

appear dull and discoloured till he attained a considerable elevation: a parching wind blew like a blast from a furnace, and heated wood, iron, and every other solid material, even in the shade; and immediately before the monsoon this wind had been succeeded by still more sultry calms. But when the first violence of the storm is over, the whole earth is covered with a sudden but luxuriant verdure; the rivers are full and tranquil; the air is pure and delicious; and the sky is varied and embellished with clouds. The effect of this change is visible on all the animal creation, and can only be imagined in Europe by supposing the depth of a dreary winter to start at once into all the freshness and brilliancy of spring. From that time the rain falls at intervals for about a month, when it comes on again with great violence; and in July the rains are at their height: during the third month they rather diminish, but are still heavy; and in September they gradually abate, and are often suspended till near the end of the month, when they depart amid thunders and tempests, as they came."*

Major Forbes, while dwelling in the moun-

* Elphinstone's Caubul.

tainous region of Ceylon, also notices the scenes of fiery conflict in the sky which are commonly perceived in all parts of Ceylon previous to a change of the monsoon; "but here, elevated amidst clouds, and mountains wooded to the summit, the effect, always sublime, is occasionally astounding, when lightnings crash through the aged forest, gleaming beneath your path in some deep valley, and quivering in its rippling stream. Within the tropics, lightning, if not more vivid, is far more varied than it appears in colder climes: it is not uncommon in the Kandian country, after a clear, sultry day, to see the approach of evening heralded by dark rolling clouds piling themselves aloft, then spreading along the sky until the advancing masses flash their electric fires; sometimes, like fluttering pennants or heraldic scrolls, they waver before the dazzled sight; and frequently, as if escaping from a grasp, blaze for an instant, then scatter through the heavens, like the thunderbolts of Jove as depicted by the ancients."

In America thunder-storms present the same grand phenomena as those already noticed in other continents. The Hon. C. A. Murray notices a magnificent thunder-storm which he witnessed

on the Missouri, in the middle of a night in June. "The whole western sky was illuminated by broad and fitful sheets of lightning, so bright at times as to light up the mighty river, and to show distinctly the bold and varying features of its banks; in a moment again all was black and still; night had thrown her mantle over the scene, and silence resumed her empire: then the thunder muttered from its distant couch, and again the brilliant illumination succeeded; the peals grew louder and louder, till at length they burst and rattled so near above us, that I could almost believe the alarmed forest trembled beneath their wrath. A torrent of rain closed the scene. I retired to my berth deeply impressed with the might of Him whose right hand launches and checks these fiery ministers."

In describing the phenomena of thunder-storms, it is natural to suppose the clouds which produce them to be elevated high in the air, far above the spectator. In mountain regions, however, storms frequently arise so rapidly that the traveller may find himself in the very midst of the thunder-cloud, or he may even see it rolling beneath him at his feet, while the sun and a pure blue sky are

smiling above him. The following are instances of this kind. M. Richard states that towards the end of August, 1750, he ascended in his carriage the small mountain of Boyer, between Châlons-sur-Saône and Tournus. At about three-quarters of the height of the mountain a cloud was suspended, in which the thunder rolled from time to time. M. Richard soon reached it. From the moment of doing so the thunder was no longer heard in sharp peals, with intervals of silence, but it made a continued noise, "similar to the rolling of a heap of nuts upon wooden planks." At the top of the mountain the observer found himself above the cloud. But the storm had not ceased; for the lightning again flashed brightly, and loud peals of thunder followed.

Another example of the same kind was related to M. Arago by his sister. "Some years ago I set off in the morning, with two of my friends, from the village of Estagel to go to Limoux. Our carriage had already accomplished a considerable part of the winding and rapidly ascending road of the Col Saint Louis, when the whole valley suddenly became covered with stormy clouds, concerning whose nature no one could

mistake, since they were ever and anon illuminated with brilliant flashes of lightning, followed with loud peals of thunder. My companions and I wished to return; but our conductor was of a different opinion, and proceeded boldly forward to meet the storm. As we were very much alarmed, we shut our eyes that we might not see the lightning, and closed our ears against the thunder. We had continued in this state for about a quarter of an hour, when the coachman informed us, to our unspeakable gratification, that all danger was over. The cloud, in truth, was now below us, where it still continued to thunder and lighten, while we above it were enjoying a pure sky and a beautiful sun."*

During the residence at elevated stations in the Pyrenees, of the military engineers employed in the great trigonometrical survey, some interesting observations on the upper surfaces of thunder-clouds were obtained. Captains Peytier and Hossard were involved on several occasions in active thunder-clouds. This was the case at the summit

* Arago's Notice, *Sur le Tonnerre,* published in the Annuaire of the Bureau des Longitudes, Paris 1837, has been of considerable assistance to the writer of this little work.

of the Peak d'Anie (8,215 feet high), on the 15th June, 1825. The storm lasted six hours; the hair of the observers and the strings of their caps all stood on end, and they also heard a buzzing noise around the projecting parts of their bodies. Again, upon the mountain of Troumouse, at an elevation of 10,124 feet, they were exposed to storms on the 9th and 13th August, 1826. The storm of the 9th lasted twenty-four hours, during which it hailed and rained considerably, and the thunder-claps were very frequent. The tent, in spite of three folds of very thick cloth, placed one over another, sometimes appeared to be all on fire. The loaded guns, left for precaution's sake on the outside of the tent, exhibited next day many traces of evident fusion at the end of the barrel. The storm appeared so violent in the valley, that the inhabitants despaired of seeing again either the two officers or their guides.

It is curious to learn how remarkably the upper surface of the thunder-cloud differs from the lower surface. When the lower surface was perfectly even and level, the upper surface was broken into ridges and protuberances rising upwards to great heights, like the surface of the earth in an Alpine

district. In times of great heat such strata were observed suddenly to send upwards lofty vertical cones, which, stretching into higher regions of the air, established by their conducting power an electrical communication between strata of the atmosphere at very different heights. This appearance was generally observed to precede a thunder-storm.

It is commonly supposed that in the wide ocean and in islands it never thunders beyond the seventy-fifth degree of north latitude; and that at the seventieth degree it is very seldom heard. It appears, however, from the direct evidence of Von Baer and other travellers, that no northern latitude has been attained by man in which thunder is not known to occur. In Nova Zembla Von Baer has witnessed a thunder-storm beyond the seventy-third degree, and he states that the narratives of the hunters of the walrus contain many accounts of it. Thunder-storms are also frequent in Iceland, though not so common as n most other parts of Europe. In Greenland thunder is more uncommon; some missionaries who resided in that country for fifteen years remark that lightnings are sometimes seen, but

that thunder is seldom heard. On the coast of Hudson's Bay, Ellis and James Hudson have witnessed thunder-storms. Even in the midst of the Polar ice thunder is sometimes heard. Admiral Wrangell, in one of the perilous journeys which he made upon the ice of the Polar Sea to the north-east of Siberia, observed a thunder-storm when out of sight of land. It even thunders at a higher latitude than 75°, and as far north as Spitzbergen, as appears from the recital of four shipwrecked Russians, who found an asylum on the eastern isle of Spitzbergen, on which three of them lived for six years and three months. They heard thunder once, and only once, during this long period.

In the Report of the British Association for 1845, there is a notice of a thunder-storm at Alten, in Norwegian Lapland, situated 69° 50′ N. lat. and 23° E. long.

FRANKLIN'S EXPERIMENT WITH THE KITE.

See p. 54.

CHAPTER II.

ELEMENTARY LAWS OF ELECTRICITY—ORIGIN OF THE TERM—TWO KINDS OR STATES OF ELECTRICITY, VITREOUS AND RESINOUS, OR POSITIVE AND NEGATIVE—ATTRACTION AND REPULSION—LIST OF ELECTRICAL CONDUCTORS—VELOCITY OF ELECTRICITY—ACCUMULATED ELECTRICITY—THE LEYDEN JAR—EFFECTS OF ACCUMULATED ELECTRICITY—THEIR RESEMBLANCE TO THOSE OF LIGHTNING—FRANKLIN PROVES THEIR IDENTITY—DALIBARD'S APPARATUS—ROMA'S GRAND EXPERIMENTS WITH AN ELECTRICAL KITE—FATAL ACCIDENT TO PROFESSOR RICHMANN.

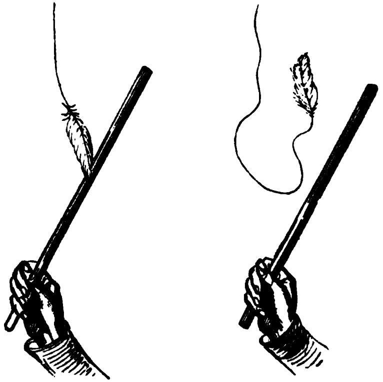
LIGHTNING, which exhibits such tremendous effects during a thunder-storm, is also known by the name of *electricity*, or the *electric fluid*. But we are quite ignorant of its real nature; and although it is everywhere present, we are not aware of its existence until it is disturbed or excited into action.

There are many ways by which this disturbance can be brought about, and the curious properties of electricity be studied. The ancient Greeks discovered that when a piece of amber was rubbed it acquired the power of drawing light bodies

towards it, or of driving them away, which is called *attraction* and *repulsion*. For many ages this was thought to be peculiar to amber, and on this account the word *electricity* was employed, the Greek word ἤλεκτρον (*elektron*) signifying *amber*. There are, however, many other substances which answer the purpose equally well; a stick of resin, rubbed with flannel, or a rod or tube of glass, rubbed with a silk handkerchief, will exhibit this property, or become, as it is called, *electrically excited*. If held near the cheek, a sensation will be felt similar to that produced by drawing a cobweb over the face. In the dark the excited bodies are faintly luminous, with a bluish light; and if the finger be held near them, a small spark will be seen to pass to it, accompanied with a slight snapping noise.

The attractive and repulsive powers of electricity can be prettily illustrated by suspending freely in the air a light downy feather, fastened to the end of a long thread of white sewing silk. If a tube of glass, about three feet long and an inch in diameter, perfectly dry and clean, be held at one end, and briskly rubbed with a warm silk handkerchief, it will soon become excited, and on

holding it within a few feet of the feather, the latter will fly up to it, and remain adhering to it. On gently withdrawing the tube, and again approaching it, the feather will no longer be attracted but repelled; and it will not be possible for some time to make the feather touch the tube. At



ATTRACTION. REPULSION.

length, however, it will be again attracted and again repelled, as before, and so on several times, until the glass has lost all traces of free electricity.

In this experiment, when the feather is attracted

by the glass, it takes from it a portion of electricity, and then suffers repulsion. The feather gradually parts with its electrity to the surrounding air, then flies to the tube for a fresh supply; is again repelled, and continues to be so until the air has brought it to a neutral condition, when it is once more attracted and again repelled. In the meantime the tube, parting with its electricity much more slowly than the feather, remains excited during these attractions and repulsions, until at length it returns to the neutral condition, and exerts no further action on the feather. We see, therefore, that the feather, having obtained a share of electricity from the glass, is immediately repelled by it, and as this repulsion is known to be mutual, we learn from this simple experiment that *bodies similarly electrified repel each other*.

Let us now repeat the experiment in precisely the same manner, only using, instead of the glass tube and silk handkerchief, a stick of resin * and a piece of dry warm flannel. The feather will first be attracted by the resin, deprive it of a por-

* A stick of red sealing-wax will answer the purpose, there being really no wax in this substance, but shell-lac, which is a *resin*.

tion of its electricity, and immediately be repelled, as in the former experiment.

It does not appear from these experiments that there is any difference between the electricity of glass and that of resin. But let us present these two excited bodies alternately to the feather, and we shall observe a remarkable difference. Excite the glass tube as before, and while it is repelling the feather, bring the excited stick of resin near it, and the feather will be immediately attracted by the resin. Or we may reverse the experiment, and first repel the feather with the excited resin, when it will be found that the excited glass will attract it. Or thirdly, the last two experiments may be combined by bringing the feather between the glass and the resin. It will then be alternately attracted and repelled, swinging to and fro between the two bodies.

It is evident from these experiments that there must be some difference between the electricities of glass and of resin, since bodies which are repelled by the one are attracted by the other. The electricity produced from glass is called *vitreous*, and that from resin *resinous* electricity: they are also known by the terms *positive* and *negative*, and

represented by the symbols + plus, and − minus; a body electrified by vitreous electricity being said to be in a *positive* state, and that by resin in a *negative*.

It will be seen from the foregoing experiments, 1. That bodies similarly electrified, whether positively or negatively, repel each other; 2. That bodies dissimilarly electrified attract each other.

We may learn another important truth by varying the simple experiments already described. While the feather is being repelled by the glass tube, bring near to it that part of the silk handkerchief which was used to rub the tube, and it will be found to attract it. Or if we first present the handkerchief to the feather, it will first attract it, and then repel it; and while in this state of repulsion, if the excited glass tube be held near, it will immediately attract the feather. Hence it is obvious that the glass and the silk are in opposite states of electricity; the glass we know to be vitreous, or positive; the silk must therefore be resinous, or negative.

A similar experiment may be performed with the resin and the flannel: while the one is repelling the feather the other will attract it; the

flannel must therefore have an opposite electricity to the resin; the latter we have called negative, the flannel must therefore be positive.

From these last experiments we arrive at the important truth that *one kind of electricity cannot be produced without the production also of the other kind:* and although it has been agreed to call the two kinds of electricity by the terms positive and negative, yet there is no doubt that one is as much a positive force as the other; for it is impossible to produce one upon any body without the other appearing somewhere, either in near or distant bodies, "just as it is impossible to pull against a fixed point without eliciting in that point an equal and opposite force."*

It has been said, that when glass is rubbed with silk the glass becomes positive and the silk negative; and that when resin is rubbed with flannel, the resin is negative and the flannel positive. That such statements are true may be proved as follows:—When the feather is repelled by the glass, bring near it the excited flannel, and it will continue to repel the feather; thus proving the electricity of the glass and of the flannel to be

* Harris.

similar. Also, while the feather is being repelled by the resin, approach the excited silk handkerchief and it will continue to repel, showing the electricity of both to be negative.

It is probable that all solid substances, if rubbed in the same manner as the glass and resin, would become electrically excited; but in a very large number of bodies the electricity would disappear as fast as it was formed. If, for example, a rod of metal were held in the hand, and rubbed with silk or flannel, it would exert no action whatever upon the feather, because all the electricity, as fast as it was formed, would flow or be conducted through the body of the operator into the earth. If, however, the rod of metal were furnished with a handle of glass or of resin, and then rubbed against a piece of dry warm flannel, it would attract and repel the feather as the glass tube and the stick of resin had done. It is evident, then, that the glass or resinous handle *insulates** the metal tube, and prevents the electricity from quitting it: other substances would do so in different degrees, and hence bodies are arranged

* To *insulate* is to separate from surrounding objects; as *insula*, an island, is separated from surrounding land.

with reference to their conducting powers. The metals are by far the best conductors; next to them come well-burned charcoal, plumbago, flame, smoke, and some strong acids; less perfect conductors are dilute acids, saline fluids, the bodies of living animals and vegetables, wood in its ordinary state, and snow and ice; among imperfect conductors are aqueous vapour, earth and stone, dry chalk and lime, marble and porcelain, paper, and alkaline substances; still less perfect conductors are ice at the zero of Fahrenheit's scale, dried vegetable and animal substances, parchment, leather, feathers, baked wood, oil and fatty substances, pitch, and silk; among the worst conductors are animal fur and hair, dry air and gases, steam at a very high temperature, glass, and all vitreous bodies, the diamond and transparent gems, talc, amber, resins, brimstone, and shell-lac. These very imperfect conductors are said to be good *insulators*, because they may be used to insulate such bodies as are electrified, thereby enabling them to retain their electricity much longer than they otherwise would do.

Some idea may be formed of the difference between a good conductor and a bad one, by the

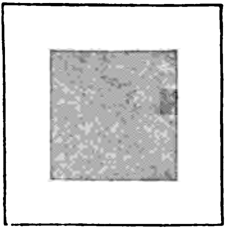
fact that iron wire conducts electricity four hundred million times better than pure water; "that is to say, electricity meets with no more resistance in passing through an iron rod four hundred millions of inches long, than it would meet with in passing through a column of water of the same diameter only one inch long." The enormous rapidity with which electricity travels along good conductors may well excite our astonishment. It has been shown by Professor Wheatstone that electricity moves through a copper wire, one-fifteenth of an inch in diameter, and about half a mile in length, at the rate of 576,000 miles in a second of time, a velocity greater even than that of light.

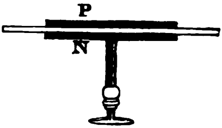
If, instead of the glass tube and silk handkerchief, a large plate or cylinder of glass be made to revolve between or against fixed cushions, we get the essential parts of the electrical machine; and by a certain other arrangement of glass and metal, are able to accumulate quantities of electricity, and study its properties.

Electricity can be accumulated in the *Leyden jar*,* the principle of which will be understood

* So called from its having been first used by Muschenbroeck at Leyden, in the year 1745.

from the following diagram, which represents a pane of glass, coated on both sides with tin-foil, so as to leave a margin of about an inch of the glass uncovered. Let this plate of glass be supported on a stand made of some good

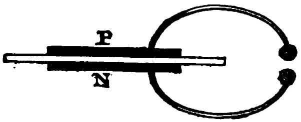




conducting material, and we shall then have the arrangement shown in section in the second figure, namely, two conducting surfaces of tin-foil, P and N, the first insulated by the pane of glass, and the other freely communicating with the earth. Now, if a charge of electricity be communicated to the surface P, an equal charge of electricity of the opposite kind will immediately be produced on the opposite conducting surface N, just as the

glass tube and the silk handkerchief, and the resin and the flannel, produced upon each other equal charges of dissimilar electricity.

These two surfaces, charged with dissimilar electricities, exert a powerful attraction upon each other, so powerful, that in some cases the glass may be fractured by the tendency of the two forces to unite. If, however, a communication be made between them by means of a good conductor, a spark of light passes, and the two surfaces are restored to their neutral or ordinary condition, in which they exhibit no traces of electricity. The two metallic surfaces can be brought together by means of brass wires terminating in knobs. A spark will pass between these knobs, the two electricities will unite, and equilibrium thus be restored. This spark will be visible only when passing between the two knobs; most electrical effects being visible only in the space between conductors.



The form of apparatus just described is by no means so convenient as that which is in common

use, namely, the Leyden jar: this is shown in the next engraving. It represents a glass jar or wide-mouthed bottle, covered with tin-foil both within and without, except a few inches near the top. The cover of the jar is a piece of mahogany, through the centre of which passes a brass wire with a knob at the top, and a chain at the lower extremity, which passes down to the bottom of the jar and

remains in contact with the inner metallic surface. On holding the knob of the jar to the electrical machine while its plate or cylinder is being turned, sparks will fly off to the knob, pass down the wire and chain into the jar, and communicate to the inner surface of the glass a charge of electricity; at the same time the outside of the jar will receive an equal charge of negative electricity. The jar is now said to be charged; and if, while holding the jar on the outside with one hand, the other hand be brought to the knob, a communication will thus be made between the inside and the outside of the jar, the

two electricities will unite, and, while doing so, will give a violent shock to the person holding the jar. The first time this shock was received by the Dutch philosophers, so much alarm was excited by the then novel and unexpected occurrence, that one of them declared he would not again receive it for the whole kingdom of France.

A number of these jars collected together form what is called the *electric battery,* and furnish the means of accumulating large quantities of the electric fluid. A large battery at Haerlem melted various metals, and scattered them about in all directions. An iron wire, twenty-five feet long and about a hundred and fortieth part of an inch in diameter, was melted by the shock into red-hot globules. A piece of tin wire, eight inches long and one-eighteenth of an inch in diameter, disappeared in a cloud of blue smoke, throwing down red-hot globules of fire. A piece of box-wood, four inches long and four inches in diameter, was rent in pieces by the shock. The machine employed to charge this battery consisted of two circular plates of glass, each five feet five inches in diameter, and were excited by means of four pairs of cushions, each cushion about fifteen inches

long and two inches wide. When this splendid machine was in action, bodies at the distance of forty feet were sensibly influenced by it; pointed wires were tipped with a star of light at the distance of twenty-eight feet; and on presenting a metal ball to the conductor of the machine, there was produced a powerful current of brilliant light more than two feet in length, crooked, and darting forth luminous brushes into the air. A single spark melted a considerable length of gold leaf, and set fire to spirits, gunpowder, and other combustibles. The accompanying engraving represents the spark produced by this splendid machine.

The discharge from such a battery as the above is sufficient to kill small animals, to render steel bars magnetic, to produce a stunning effect by its report,

and a flash of light so intense as to dazzle the sight.

Such effects as these produced by the electrical machine would naturally remind the observer of lightning. That there was some connexion, if not identity, between electricity and lightning, had long been suspected. Mr. Gray, in the Philosophical Transactions for 1735, observed that "the electric fire seems to be of the same nature with that of thunder and lightning;" and the Abbé Nollet, in his lectures on Natural Philosophy, in 1748, spoke more clearly of the analogy between them. "If any one," he says, "should take upon him to prove, from a well-connected comparison of phenomena, that thunder is, in the hands of nature, what electricity is in ours; that the wonders we now exhibit at pleasure are small imitations of those great effects which alarm us, and that the whole depends upon the same kind of mechanism; should it be shown that a cloud, formed by the action of the winds, by heat, and by a mixture of various exhalations, is, when opposite to a terrestrial object, as an electrified body when at a certain distance from one that is not electrified, I confess such an idea, if well supported, would afford me

infinite pleasure, and that it may be supported by many plausible arguments, is obvious to any one versed in the history of electrical phenomena. The universality of the electric matter, the rapidity of its action, its heat, and its activity in inflaming bodies; its property of striking them externally and internally, even to their smallest parts; the remarkable instance we have of this effect in the Leyden experiment, the notion which may be legitimately adopted of the effects that might be supposed to arise from a much greater accumulation of electric power; these, and many other points of analogy which I have for some time meditated upon, almost induce me to believe that in taking electricity as a foundation, one might form much more perfect and plausible hypotheses respecting the origin of thunder and lightning, than any that have hitherto been suggested."

While the scientific men of Europe were thus meditating upon the similarity of the effects of electricity and lightning, Dr. Franklin, in America, was preparing a grand experiment to test their identity. The analogy between lightning and electricity had long excited his admiration, and the principal differences which he saw between

them were only in degree. "It is no wonder," he says, "that the effects of the one should so far exceed those of the other; for if two gun-barrels, when electrified, will strike at two inches distance, and make a loud report, at how great a distance may ten thousand acres of electrified cloud strike, and how loud must be the crack?" He then remarks that flashes of lightning are generally crooked and waving, and so is a long electric spark; that lightning, like common electricity, strikes the highest and most pointed objects in its way, in preference to others, such as hills, trees, towers, spires, masts of ships, points of spears, &c.; that it takes the readiest and best conductor; that it sets fire to inflammable bodies, rends others to pieces, and melts the metals. Lightning, he adds, has often been known to strike people blind, and the same happened to a pigeon which had received a violent shock of electricity; in other cases it has killed animals, and they also have been killed by electricity.

Having observed that pointed conductors appear to attract electricity, Franklin supposed that pointed rods of iron attached to buildings might draw from the clouds their electricity, without

noise or danger, and convey it to the earth. "The electric fluid," he writes, "is attracted by points; we do not know whether this property be in lightning, but since they agree in all particulars in which we can already compare them, it is not improbable that they agree likewise in this. *Let the experiment be made.*"

The method in which Franklin proposed to make this experiment was, to erect on some high tower or other elevated place, a sentry-box, from which should rise a pointed iron rod, insulated by being fixed in a cake of resin. Electrified clouds passing over this would, he conceived, impart to it a portion of their electricity, which would be rendered evident to the senses by sparks being emitted when a key, or other conductor, was presented to it. At this time there was no elevated building in Philadelphia adapted to the experiment; and while he was waiting for the erection of a spire to a church then in course of building, the happy thought occurred to him that he might more readily attain his object by means of a common kite. He prepared one by fastening a silk handkerchief to two cross sticks, the silk not being so liable to injury from rain as paper. To the upright stick was

affixed an iron point, and the lower extremity of the string terminated in a length of silk. A key was fastened to the part where the silk and the hemp were joined. With this simple apparatus Franklin went out into the country on the first appearance of a thunder-storm, accompanied by his son, to whom alone he communicated his intentions. He stood under a shed to avoid the rain; his kite was raised, a thunder-cloud passed over it, but no indications of electricity were obtained. He almost despaired of success, when all at once he observed the loose fibres of the string to bristle upwards; and on holding his knuckle to the key he received a strong spark. Before the rain had wetted the string other sparks were obtained; but when the string was thoroughly wet, abundance of electricity was procured.*

About a month before Dr. Franklin had made these successful trials, two French philosophers, Messieurs Dalibard and Delor, who seem to have been acquainted with Franklin's proposed method of elevating pointed metallic conductors high in the atmosphere, had obtained similar results. Dalibard's apparatus, which was erected at Marly

* See Frontispiece to this chapter, p. 34.

near Paris, consisted of a rod of iron forty feet long, the lower end of which was brought into a sentry-box; the rod was fastened on the outside to three wooden posts by means of silken cords defended from the rain. On Wednesday the 10th of May, 1752, between two and three in the afternoon, a clap of thunder was heard, and the man entrusted with the care of the apparatus in M. Dalibard's absence, called the curate of the parish and several other persons together, and in their presence drew sparks from the conductor. A few days afterwards a similar result was obtained by M. Delor at Paris.

But the grandest experiments of this kind were made by M. Romas* with an electrical kite. This kite was seven feet five inches high, and three feet in its greatest width, with a surface of eighteen square feet. The string of the kite was wrapped round with copper wire. On the 7th of June, 1753, on the first indications of a thunderstorm, he raised the kite in the air, and at half-past two o'clock in the afternoon it was soaring at the height of about 550 feet. To the extremity of the string, which was 780 feet long, he fixed a

* Judge of the Presidial Court of Nerac, in Aquitain.

silken cord three and a half feet long, attached to a large stone placed under the cover of a pent-house. Near the junction of the string and the silk cord was placed an iron tube about a foot long and an inch in diameter, from which sparks were to be drawn as soon as the kite was electrified. In order to prevent these sparks from passing through the body of the operator, a discharging rod was prepared; this was formed of a tube of glass twelve inches long, having at one end a tube of iron, to which was fixed a chain of brass wire sufficiently long to touch the ground while sparks were being drawn from the first iron tube. By means of this rod M. Romas first obtained sparks similar to those given off by a moderately sized electrical machine. In about twenty minutes these electrical effects ceased; but after waiting seven minutes the electricity reappeared and again decreased, but only to display itself with additional force. Sparks were drawn by the fingers, the keys, the swords, and the canes of the spectators; and M. Romas having presented the middle knuckles of his right hand, received a terrible shock, which struck him in the elbows, shoulders, breast, knees, and joints of the feet.

Seven or eight of the bystanders, though they saw, from the convulsive motions of M. Romas, that he had received a very violent shock, did not hesitate to join hands, and receive the sparks. The storm now increased—no rain had fallen; but above and around the kite were black clouds, which indicated a great increase of electricity. Romas had, therefore, the prudence to receive sparks only by the discharging-rod. At the distance of four inches, a spark more than an inch long and two lines broad, was drawn in this manner; and at the distance of six inches sparks were obtained two inches long. After this the electricity became so powerful, that, instead of sparks, flashes of fire, about a foot long, three inches wide, and three lines in diameter, were repeatedly received, with a noise which was heard at the distance of more than 500 feet. At this time, when he was more than three feet from the cord, Romas felt a sensation as if a spider's web had been upon his face. He advised his assistants to keep at a greater distance. When he was five feet from the string he experienced the same sensation. He then retired still farther, and watched the phenomena which took place. There was

no lightning, almost no sound of thunder, and no rain. The wind, which was in the east, blew strong, and supported the kite at an altitude of about 650 feet. On looking at the iron tube, at the junction of the string and the silk cord, which was about three feet distant from the ground, he was surprised to observe three straws standing erect, and dancing up and down below the iron tube. This dance of the straws, which greatly delighted the spectators, lasted about a quarter of an hour, when a few drops of rain fell, and Romas again felt the former sensation upon his face, which indicated a new increase of electricity and prevented him from drawing sparks even with the discharging rod. At the same time was also heard a continued rustling noise like that of a small forge bellows. Having advised every person to keep at a greater distance, he perceived the largest straw attracted by the iron tube, and immediately heard three loud noises, which some compared to the crack of a postilion's whip, others to the explosions of rockets, and others to the sound of large earthen jars dashed in pieces on the pavement. This crash was heard even in the centre of the town, in spite of the great noise

that prevailed. The flash which accompanied the explosion was spindle-shaped, eight inches long, and four or five lines in diameter. The straw which occasioned this noise followed the string of the kite, and was seen even at the distance of forty and fifty fathoms, going up with great rapidity, being sometimes attracted and sometimes repelled; and every attraction being accompanied with long sheets of fire and explosions. After the first explosion, till the end of the experiment, no lightning was seen and scarcely any thunder heard. A sulphurous odour, peculiar to the electric matter, was very perceptible. The string appeared to be surrounded with a luminous cylinder, three or four inches in diameter; and when the experiment was concluded, a hole was seen in the ground below the iron tube, about an inch deep and half an inch wide, which had probably been made by the large flashes which accompanied the explosion. The wind having turned to the east, a heavy shower of rain came on, succeeded by hail, and it was no longer possible to keep up the kite. When the kite fell, the string touched the roof of a house, and about eighty fathoms of the string being drawn in, the person who held it made the kite

rise again, and immediately received such a violent shock that he was obliged to let it go. The string then fell upon the feet of one of the assistants, who also received a very violent shock.

On the 16th of August, 1757, M. Romas obtained still more remarkable results. Sparks nine or ten feet long and an inch in diameter were given off from his apparatus, and they were accompanied with a noise equal to the report of a pistol. But such experiments as these had already received a considerable check in the lamented death of Professor Richmann of St. Petersburg, while employed in bringing down electricity from the clouds. On the 16th of August, 1753, while attending a meeting of the Academy of Sciences in the forenoon, his attention was excited by the sound of distant thunder. He immediately set off for his own house, where his apparatus was erected, taking with him the engraver Sokolow, whom he had engaged to make drawings of any effects that might be produced. While the professor was stooping down to see the amount of electricity indicated by the electrometer, a large globe of bluish-white fire flashed from a metal conducting rod, with a report as loud as that of a pistol. The

professor fell back upon a chest behind him and instantly expired. Sokolow was stupified and benumbed by the shock, and was struck by several fragments of red-hot wires; but the moment he recovered he ran out of the house calling for help. In the mean time Mrs. Richmann, who heard the stroke of the thunder, hastened to the room and found her husband sitting lifeless upon the chest. The house was filled with a sulphurous vapour; a clock in an adjoining room was stopped; the ashes were thrown from the fire-place, and the door-posts of the house were rent asunder. Medical aid was of no avail to the professor; a red spot appeared on his forehead, and several red and blue spots were found on the left side, on the back and other parts of the body. The shoe on the left foot was burst open; and below the aperture was a blue mark on the foot from which it is probable the electricity had issued. The stocking was entire at the place where the shoe was burst, and the coat had received no damage. The back of the engraver's coat, however, was marked with several long and narrow stripes, as if red-hot wires had burned off the nap.

SHIP STRUCK BY LIGHTNING.

CHAPTER III.

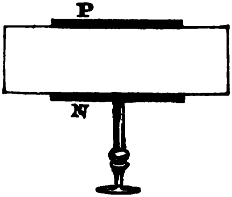
ELECTRICAL CONDITIONS OF A THUNDER-STORM—THE CLOUD AND THE EARTH IN OPPOSITE ELECTRICAL STATES—HOW THIS IS BROUGHT ABOUT—DISRUPTIVE DISCHARGE—PASSAGE OF LIGHTNING THROUGH GOOD CONDUCTORS—THROUGH A SYSTEM OF GOOD AND BAD CONDUCTORS — CAUSE OF DAMAGE FROM LIGHTNING—SHIPS WITHOUT A CONDUCTOR STRUCK BY LIGHTNING AND SET ON FIRE — SHIP WITH IMPERFECT CONDUCTOR STRUCK—HOUSE STRUCK BY LIGHTNING—CURIOUS EFFECTS.

LET us now endeavour to explain some of the leading phenomena of a thunder-storm by means of the electrical principles explained in the last chapter.

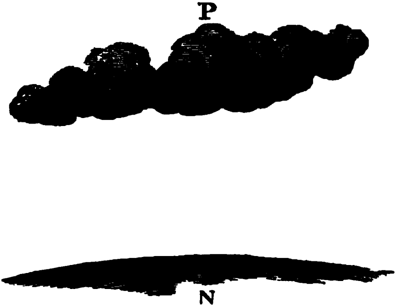
It was shown that one kind of electricity cannot be produced without the production also of the other kind. By the friction of the glass tube with the silk handkerchief one is rendered positive and the other negative; the stick of resin is negatively electrified by the flannel, which in its turn becomes positive; the square of glass positively electrified on one surface becomes negative on the other.

In these cases the two opposite electricities are developed very near to each other. In the glass

plate they are separated only by the thickness of the glass. Let us now suppose this thickness to be greatly increased; that instead of a thin pane of glass one-sixteenth of an inch thick we have a block of glass several feet thick, partly covered as before with tin-foil, the metallic surface P being insulated, while N communicates with the earth.

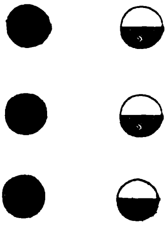


On communicating a charge of positive electricity to P, there will immediately be negative electricity at N. Now, suppose that instead of this arrangement P is a collection of clouds, N a

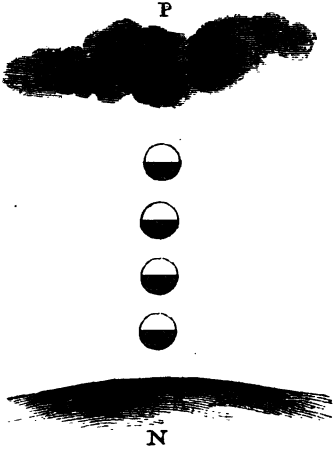


portion of the earth's surface immediately below them, and that the air between them is the insulating body instead of glass. The clouds being positively electrified, will throw that portion of the earth's surface N immediately under them into an opposite state. The method by which this is supposed to be brought about must now be noticed.

When bodies exhibit no signs of electricity, but are in what is called their *neutral* state, or in *equilibrium*, the electricity is equally distributed among them. Suppose the shaded circles to represent particles of air in a neutral state, with the electricity equally diffused in each particle; suppose next that these particles are electrified: we may then imagine all the electricity of one kind to be accumulated in the upper half of each particle, and all the electricity of the other kind to be in the lower half, as represented in the second group of circles. Now this sort of action goes on in the air from particle to particle, between the thunder-cloud



and the earth or sea immediately beneath it. Let us trace the progress of four particles of air between the cloud and the earth; if the cloud be positive,



the upper half of the first particle will be made negative and the lower half positive; this lower half of the first particle acting on the upper half of the second particle will render it negative; the second half of the second particle will be +; this

will render the upper half of the third particle — ; and the lower or + half of the third particle will render the upper half of the fourth particle — and the lower half +, which will render the earth beneath it —. Now as we know that the cloud P may present to the earth a surface of several hundred square acres, and as the space between the cloud and the earth P and N is occupied with innumerable myriads of aerial particles, all being acted upon after this manner, some idea may be formed of the enormous quantity of electricity disturbed. And as we know from the experiment of the tube and the feather, that bodies in opposite states of electricity attract each other and tend to combine, so these particles of air, the thunder-cloud and the earth, exert an attraction towards each other, which becomes more powerful as the electrical excitement continues, until at length the two opposite electricities rush together with violence, producing what is called the *disruptive discharge*, or, in other words, the well-known phenomena of lightning and thunder.

It is of no consequence in the above arrangement, whether the cloud be positively or negatively electrified; the effect is the same. If the cloud

be negative, that portion of the earth beneath it will be positively electrified.

If we suppose a good metallic conductor of sufficient size to proceed from the earth N up to the cloud P, it is obvious that the electricity would be drawn quietly down into the earth without any, or at least with only a very small excitation of the intermediate air. If this rod were composed of good and bad conducting substances, such as the ordinary materials of a church tower, the lightning would pick out, as it were, the easiest path, moving with facility along metallic bodies, and even appearing to go out of its way to pick them out. So long as it moves along a good conductor it does no harm, but the moment it meets with bad conductors which delay its passage even for an instant, the destructive powers of the lightning accumulate with fearful rapidity; its heating power is so intense, that the moisture in wood and stone is probably instantly converted into high-pressure steam, which acting with explosive energy expands and shatters the substances in which it is so suddenly created.

It appears, then, from these details that the electrical conditions of a thunder-storm consist in this:

The conducting surfaces of the clouds and the earth are the terminating planes of a highly excited mass of air which separates them; and this state of things continues until the electrical excitement of the air has attained its highest pitch, so that any tendency to further excitement renders the air incapable of resisting the combination of the two opposite electrical forces P and N. The whole system of electrified particles of air becomes overturned, and a violent reunion of those opposite forces instantly takes place. Such a discharge is generally of a sudden and violent character, and is the cause of the damage to imperfectly conducting bodies on the earth's surface, or, in other words, such is the origin of the numerous accidents from lightning to houses, churches, ships, trees, and even to individuals.

The reader will now be prepared to understand the cause of the damage from lightning in the cases we are about to relate, and to appreciate the means employed for securing buildings and ships from the destructive action of this terrific agent. While ships remain unprovided with lightning-conductors, there is no danger incident to their perilous position on the ocean to which they may

not be suddenly and unexpectedly assailed. They may be burned, sunk, or severely damaged. In short, lightning is the cause of shipwreck in every possible form.

The following is one of the many instances of a ship being sent out to sea, and into a climate remarkable for the violence of its thunder-storms, with absolutely no protection whatever from the ravages of lightning.

The ship *Bayfield,* 400 tons burden, Captain Lucas, while on a voyage from Liverpool to Bonni, near Sierra Leone, encountered a terrific thunder-storm on the 25th November, 1845. The master and crew were on deck at their several posts ready to act at the instant notice. About midnight the lightning struck the main and mizen-mast head with a fearfully violent shock. The captain and most of the crew near him were knocked down almost senseless by the shock, and did not recover for some minutes. The lightning passed down the masts into the ship's hold, scattering large splinters and balls of fire over the deck, fore and aft. The ship's timbers trembled under the shock. The storm continued to rage in all its fury, and in the course

of half an hour the crew, nearly exhausted by their previous exertions, discovered that the lightning had set fire to the ship. A rush was made to the boats, and had it not been for the firmness of the captain, the whole crew would probably have perished. Acting under his directions, the after-hatches were removed in order to let in the water, when a body of flame instantly shot up some feet above the deck. Water was thrown into the hold, and the hatches immediately replaced, with the view of smothering the fire. It was now discovered that the flames were raging immediately over the powder-magazine; and fearing an explosion every instant, it was determined to abandon the ship. It was exceedingly difficult to launch the boats in so fearful a storm, as it required the greatest care to prevent their being dashed to pieces against the vessel's sides. At length they succeeded in getting into the boats, and pushed off, and laid-to about a mile from her until daybreak, by which time she had drifted about five miles south-east from the spot where the boats were lying. Perceiving that the flames had not extended over her so rapidly as they anticipated, and being entirely destitute of provisions, they resolved to

return to the burning ship. Having reached her and crawled up the sides on to the deck, they found her to be on fire fore and aft. The smoke was rushing from every aperture in dense volumes, and the deck was so hot aft the mainmast that it was impossible to walk over it. To get to the fore-hold, where the fresh water was stowed, was utterly impossible, and fancying every moment the ship would blow up, they took to the boat once more, unable to save any thing in the shape of provisions, except about thirty pounds of sea-biscuit bread. They managed, however, to secure a compass. During the whole of that day they remained in sight of the flaming vessel, the fire raging with terrific fury. At sunset she appeared to be drifting away, and later in the evening the only thing they could distinguish of her was the bright reflection of the flames in the horizon. She was seen by other vessels to blow up about two o'clock on the following day. The unfortunate fellows in the boat steered a course for Sierra Leone, which they succeeded in gaining after undergoing the most severe sufferings during eight days and nights. All they had to live upon was the thirty pounds of biscuit,

which, divided amongst so many, gave to each poor fellow but a very scanty allowance. The want of water also considerably increased their misery, especially as they were close to the line under a tropical sun. When they reached the shore three of the unhappy men had perished; and the appearance of the survivors was most pitiable, but by proper nourishment and kind attention they speedily recovered.*

The following is another fearful illustration of the danger of sending a ship out to sea without lightning-conductors.

The *Poland* sailed from New York on the 11th of May, 1840, with sixty-three persons on board, including ladies and children. With good weather and favourable breezes they went on prosperously until the 16th, when, at two o'clock in the afternoon, a squall set in, and a severe shower came on, with large drops, such as fall in hot and sultry weather. Most of the male passengers were in the house on deck, looking out at the rain and the sea. Captain Anthony, standing at the door, saw a large ball of fire apparently about twice the size

* Abridged from details furnished by Captain Lucas to the Nautical Magazine.

of a man's hat, descend nearly horizontally from the clouds, which appeared to be meeting from different points overhead. It struck the end of the fore-top-sail yard on the left-hand side, descended the ties, or some chains, to the end of the fore-yard, and ran on the yard to the cap of the fore-mast, where it exploded with the noise of a cannon, throwing out rays in every direction like the rays of the sun. The whole was instantaneous: it came and passed off in a flash, and was followed almost at the same instant by a peal of thunder, sharp and loud, but not long or rumbling.

A strict examination was now made to ascertain whether the ship was on fire. Signs of lightning were discovered in the forecastle, but it was for some time impossible to determine the extent of the danger. It was necessary, however, to prepare for the worst. The captain himself assisted in clearing the main hatch, and throwing overboard empty casks, and other lumber which was stored round the long boat. The mate with another gang of hands was at the fore hatch; and in a few minutes all hands, including many of the cabin and steerage passengers, were at work hoisting out and throwing overboard flour and cotton. This went on

amid severe rain until eight in the evening, when the forward lower hatch being reached, the awful fact became apparent that the cotton in the lower hold was on fire. The hatch was immediately closed as tight as possible, the upper hatches were also closed and partially caulked, and preparations were made to get out the boats. The women and children were brought on deck, and the captain firmly but quietly gave his orders, which were obeyed in the same spirit by his men. He forbade the bringing up of any but light articles, as the boats would not be able to carry baggage. One therefore caught up a carpet-bag, another a cloak, some opened their trunks and took out their money, leaving every thing else behind them; and some caught blankets from their berths. The steward got a barrel of bread, and others assisted him in putting whatever of eatables there was in his pantry into bags, &c. A barrel and two or three jugs of water were put into the long boat, with such coats, cloaks, &c. as could be got together in a few minutes, and then she was launched overboard. The women and children, the cabin passengers, all except three, a few of the steerage passengers, the second mate, and four sailors, formed

the crew, thirty-five in number. The boat thus laden was pushed off at ten o'clock at night, having a line attached to her and the ship. Those who remained on board the *Poland*, waited anxiously the first break of morning, to learn the fate to which they were doomed: two boats remained to them, but not more than half their number could possibly get into them. During the night the steward succeeded in getting from the cabin the captain's watch, chronometer, and trunk, with a small box of specie; but gas and smoke prevented further attempts, and all the doors to the cabin were obliged to be closed up. Captain Anthony and his companions walked the deck all night, and when morning broke, alas! there was no sail in sight. The fine ship lay on the broad ocean smoking at every crack, with three frail boats attached to her by a single rope, and no hope of rescue, except through the goodness of the Almighty. But there did appear to be a confidence in the breasts of many that God would not leave them to perish on that desert sea.

The next day, which was Sunday, was passed in the same suspense. The cracks whence the smoke issued were continually stuffed with cotton,

or plastered with pipe-clay. The ice-house on deck contained fresh meat, such as beef, ducks, chickens, &c., and the cooks were employed all the day in cooking. Warm coffee, fresh milk, and boiled fowls, were sent to the crew of the long boat, and every exertion made to lighten their sufferings. Meanwhile the deck grew quite warm, and it became necessary to put on the wooden shutters to the sky-lights on deck, and to lower a man at the stern to nail down the shutters to the cabin windows, which did not, however, prevent the smoke from coming through. Night came on, and yet no help arrived. The unfortunate people on board sank to sleep from mere exhaustion, leaving three watchers to give notice of the bursting out of the flames. One of these watchers says: "No language can tell the sufferings of that night. We were like people confined on the top of a burning mine, with no power to escape—death almost certain to be our portion within a few hours, and our minds tortured with suspense." About two o'clock the weather became more boisterous, and the people in the boat hailed the ship, wishing to be taken in. The captain begged them to wait patiently till day. At the same

time, he found that the fire had evidently increased, the deck and hatches being hot, and the pitch beginning to boil or melt in the seams between the planks. He knew that not more than fifteen out of those on board could be saved in the remaining boats, and he decided on sticking to his vessel to the last.

But the condition of those in the long boat became at last so perilous that it was absolutely necessary to take them again on board the vessel—a sad alternative; for if the fire broke out suddenly, it would be impossible to get them into the boat again, and all must perish. When they were brought on board, they were found in a sad condition. The females especially, from sitting for two nights and a day in a cramped position, with their feet in water, and dashed every moment with the spray of the sea, were great sufferers. One of them had held her child in her arms the whole time; and another had watched her little infant ready to die for the want of its natural nourishment, which the poor mother could no longer afford. It was therefore a present relief to assemble once more on the quarter-deck, although all felt that they had probably met together to

struggle and to die. Sail was now made on the ship, and an observation taken at noon by which it appeared that they were in the track of vessels to and from Europe and the United States. This inspired confidence; and the men worked vigorously at the pumps, for the vessel was found to have leaked a good deal.

At two o'clock on this day (Monday) a sail was seen from the mast-head, and soon after from the deck. The joy this discovery excited was so wild and excessive, that it seemed as if many would lose their senses altogether. The stranger saw the signals of distress and hove-to. It proved to be the *Clifton*, Captain Ingersoll, bound from Liverpool to New York, with 250 steerage passengers, mostly Irish. The boat of the *Clifton* and that of the *Poland* were now engaged from three o'clock till nine, the sea being rough, in passing and re-passing with people and articles saved from the ship. Captain Ingersoll received the sufferers very kindly, and when all were on board, made sail as quickly as possible, leaving the unfortunate *Poland* to burn up and sink, a fate which she must have met within two or three

hours, for when the last boat's load was putting off, the deck was too hot to stand upon.*

In the following case the ship had a lightning-conductor on board, but it was not in its place when wanted, and when mounted proved to be of bad construction and of insufficient size.

The *New York* packet ship sailed from New York in April, 1827, and on the third day of her voyage, while in the Gulf Stream, was struck by lightning at about daybreak. The passengers being still in their berths were roused by a heavy report like that of a cannon close to their ears, and the cabin was filled with a dense smoke, smelling like sulphur. It had been broad daylight, but was now almost dark as night. Rain fell in torrents; hail covered the deck; the lightning and thunder were almost simultaneous; the sea ran very high, and the water being at 74° Fahr. while the air was only 48°, the copious evaporation produced pillars of condensed vapour reaching to the clouds. The scene was one of terrific sublimity. Some parts of the ship and spars were

* Abridged from the Boston Courier.

for a moment on fire, but were quickly extinguished by the rain.

The lightning first struck the main royal mast, burst asunder three stout iron hoops with which it was bound, and shattered the mast-head and cap. It passed down the mainmast, one branch entered a store-room and demolished the bulkheads and fittings; thence it entered the cabin, and, conducted by a lead pipe, passed out through the ship's side between wind and water, starting the ends of three five-inch planks. During its progress it burst open the harness casks, shivered to pieces the large looking-glass in the ladies' cabin, and, being conducted by the quicksilver on the back, it left the frame uninjured; it overturned the pianoforte, split into several pieces the dining table, and so highly magnetized the chronometer as to render it useless for the remainder of the passage. Most of the watches which were under the gentlemen's pillows were so highly magnetized as to stop them, and render it afterwards necessary to remove all the steel work. The gentlemen themselves were uninjured, probably on account of the non-conducting properties of the beds upon which they were sleeping. The polarity of all

the compasses on board was also affected; knives and forks, and other articles of steel or iron also became magnetized.

At the time the ship was struck, the lightning-conductor had not been put up, but immediately after the first stroke it was raised to the main royal mast-head. This conductor consisted of an iron chain, with links one-fourth of an inch thick, and two feet long, turned into hooks at each end; its upper extremity was furnished with an iron rod half an inch thick and four feet long, having a polished point, and rising two feet above the main-mast; the chain descended down over the quarter, and being pushed out from the ship's side about ten feet by an oar, descended a few feet below the surface of the water.

The storm continued to rage during the morning. At about two o'clock P.M. it was observed that only four seconds intervened between the flash and the report. At this time there was a flash and a shock similar to that at daybreak; the passengers in the cabin saw what appeared to be a ball of fire darting before them, while the glass windows in the round-house came rattling down. To those on deck the ship appeared to be in a

blaze, so vivid was the flash which they saw distinctly darting down the conductor and agitating the water. All parts of the ship, as before, were filled with smoke, smelling of sulphur.

Although the conductor was of the size which Dr. Franklin thought sufficient to sustain the severest shock of lightning without injury, yet it was literally torn to pieces and scattered to the winds. The pointed rod at the top of the conductor was fused, and several inches of it burnt away, while the remainder was covered over with a dark coating; some of the links of the chain had been snapped off, and others melted.

Happily, no person was killed, although several were knocked down and more or less injured.*

It is curious to notice in the preceding details the devious path of the lightning. It took advantage of all the metallic bodies in its passage as stepping-stones to facilitate its descent to the earth or sea. Similar effects are observable in the case of a house in America struck by lightning, the details of which have been described by Professor Henry. The lightning struck the top of the chimney,

* Abridged from the American Journal of Science.

passed down the interior of the flue to a point opposite a mass of iron placed on the floor of the garret, where it pierced the chimney; thence it passed explosively, breaking the plaster, into a bed-room below, where it came in contact with a copper bell-wire, and passed along this horizontally and quietly for about six feet; thence it leaped explosively through the air, a distance of about ten feet, through a dormer window,* breaking the sash, and scattering the fragments across the street. It was evidently attracted to this point by the upper end of a perpendicular gutter, which was near the window. It passed silently down the gutter, exhibiting scarcely any mark of its passage until it arrived at the termination, about a foot from the ground. Here, again, an explosion appears to have taken place, since the windows of the cellar were broken. A bed in which a man was sleeping at the time, was situated against the wall, immediately under the bell-wire, and although his body was parallel to the wire, and not distant from it more than four feet, he was not only uninjured, but not sensibly affected. The size of the

* A window projecting from the roof.

hole in the chimney, and the fact that the lightning passed along the upper wire without melting it, show that the discharge was a small one, and yet the mechanical effects in breaking the plaster and projecting the window-frame across the street, were astonishingly great.

These effects the professor attributes to a sudden expansive force developed in the air along the path of the discharge. Indeed, he conceives that most of the mechanical effects which are often witnessed in cases of buildings struck by lightning, may be referred to the same cause. In the case of a house struck near Princeton, the discharge entered the chimney, burst open the flue, and passed along the cockloft to the other end of the house; and such was the explosive force in this confined space, that nearly the whole roof was blown off.

Mr. Darwin describes some curious effects of lightning which struck the house of Mr. Hood, the consul-general at Monte Video, in South America. "The paper for nearly a foot on each side of the line where the bell-wires had run, was blackened. The metal had been fused, and although the room was at least fifteen feet high, the globules dropping on the chairs and furniture, had

drilled in them a chain of minute holes. A part of the wall was shattered as if by gunpowder, and the fragments had been blown off with force sufficient to dent the walls on the opposite side of the room. The frame of a looking-glass was blackened, and the gilding must have been volatilized, for a smelling-bottle which stood on the chimney-piece was coated with bright metallic particles, which adhered as firmly as if they had been enamelled."

Calm is the sea once more, the storm is past;
And harmless lightnings play upon the mast;
Well pleased the seaman views the meteor pale,
And spreads the canvass to the favouring gale.

CHAPTER IV.

VARIOUS FORMS OF LIGHTNING — ZIGZAG — SHEET LIGHTNING — GLOBULAR LIGHTNING — OBSERVATIONS ON THESE FORMS OF LIGHTNING — EXAMPLES OF FIRE-BALLS — PROBABLE CAUSE OF — THUNDER, HOW PRODUCED—ROLLING OF THUNDER—INTERVAL BETWEEN THE LIGHTNING AND THE THUNDER—METHOD OF CALCULATING THE DISTANCE OF THE CLOUD—SUMMER LIGHTNING—CAUSE OF—THUNDER WITHOUT LIGHTNING—ST. ELMO'S FIRE—ANCIENT NOTIONS OF—MODERN EXAMPLES—EXPLANATION OF—BRUSH DISCHARGE—GLOW DISCHARGE—AMUSING INSTANCES OF THE BRUSH DISCHARGE.

According to M. Arago, the phenomena of lightning admit of three divisions:—*First*, those luminous discharges which present the appearance of narrow well-defined threads or lines of light; they are not always white, but are sometimes of a violet or purple hue; and they move in a zigzag course. This is probably the only form of lightning which strikes terrestrial objects; it always proceeds from a single point, and frequently divides into two or more distinct streams. *Second*, those

lightnings which appear to be spread over extensive surfaces, and are commonly called *sheet lightning;* they vary in colour, being frequently of an intense red, but occasionally blue and violet; they are generally confined to the edges of clouds, but sometimes seem to issue from the interior, when the clouds, in popular language, appear *to open.* This is the most common form of lightning, and has neither the activity nor the danger of the first class. *Third, globular* lightning, which appears like a luminous ball or globe of fire; it moves through the air at a comparatively slow rate, while lightnings of the first and second class exist but for a moment.

Sir W. Snow Harris* thinks it is more than probable "that many of these phenomena are at last reducible to the common progress of the disruptive discharge, modified by the quantity of passing electricity, the density and condition of the air, and the brilliancy of the attendant light. When the state of the atmosphere is such that a moderately intense

* The writer is anxious to acknowledge the kindness of his friend, Sir W. Snow Harris, in placing at his service many valuable books and papers, both published and unpublished, on the nature of thunder-storms.

discharge can proceed in an occasionally deviating zigzag line, the great nucleus, or head of the discharge, becomes drawn out, as it were, into a line of light visible through the whole track; and if the discharge divides on approaching terrestrial objects, we have what sailors call *forked lightning.* If it does not divide, but exhibits a long rippling line, with but little deviation, then they call it *chain lightning.* What sailors term *sheet lightning,* is the light of a vivid discharge reflected from the surfaces of distant clouds, the spark itself being concealed by a dense intermediate mass of cloud, behind which the discharge has taken place. In this way an extensive range of cloud may appear in a blaze of light, producing a truly sublime effect. The appearance termed *globular lightning* may be the result of similar discharges; it is no doubt always attended by a diffusely luminous track; this may, however, be completely eclipsed in the mind of the observer by the great concentration and density of the discharge, in the points immediately through which it continues to force its way, and where the condensation of the air immediately before it is often extremely great. It is this intensely illuminated point which gives

the notion of globular discharge; and it is clear, from the circumference of air which may become illuminated, the apparent diameter will be often great."

The following are a few examples of globular lightning. In a communication to the Royal Society, Mr. Chalmers states that when on board the *Montague*, a seventy-four gun ship, he was taking an observation on the quarter-deck on the 4th of November, 1749, when one of the quarter-masters requested him to look to windward; "upon which he observed a large ball of blue fire rolling along on the surface of the water, as big as a mill-stone, at about three miles' distance. Before they could raise the main tack, the ball had reached within forty yards of the main chains, when it rose perpendicularly with a fearful explosion, and shattered the main topmast in pieces." It is important to remark that at the time of this occurrence the clouds were in rapid motion, and the fire-ball on the surface of the sea appeared to move with the same degree of speed; so that it was probably nothing more than a disruptive discharge between the sea and the clouds, producing the usual phenomena of thunder and

lightning, termed, by the observers, the "rising of the ball through the mast of the ship." A somewhat similar case occurred a short time ago in Cornwall. Some preventive officers were in a vessel in the Helson river engaged in guarding a foreign ship, when they saw a large ball of fire rolling along upon the water, having the appearance of a tar-barrel on fire. It passed not far from the ship, proceeded down the river, and went out to sea.

The following remarkable phenomena accompanying electrical discharges of the clouds have been by many electricians regarded as cases of globular lightning; but they are not easy to explain on the principle of sudden and intense electrical discharges.

A house in Dorking, in Surrey, was struck by lightning on the 16th of July, 1750. Those who witnessed the accident declared that they saw large balls of fire in the air around the damaged house. In falling to the earth, or upon the roofs of the houses, these balls separated into numerous parts, which were scattered about in all directions. In 1772 a ball of light appeared in the parlour of a house struck by lightning at

Steeple Ashton. This ball is described as being of the size of a sixpenny loaf, and surrounded with a dark smoke, and is said to have burst with a loud noise. In June 1826, a fatal accident happened to two young ladies on the Malvern Hills, in which the electric discharge is said to have appeared as a mass of fire rolling along the hill towards the building in which the party had taken shelter.

In these and a large number of similar cases which might be cited, it is difficult to offer an explanation on the principles applicable to the ordinary electric spark; "the amazing rapidity with which this proceeds, and the momentary duration of the light, renders it almost a matter of impossibility that the discharge should appear under the form of a ball of fire; it would be a transient line of light."* The distinguished electrician here quoted thinks it highly probable that in many cases fire-balls are produced by a kind of discharge to be noticed presently, called the *glow* or *brush discharge* in certain points of an excited system of air, and preparatory to the more general and rapid union of the electrical forces;

* Harris.

"whilst the greater number of discharges described as globular lightning are, most probably, nothing more than a vivid and dense electrical spark in the act of breaking through the air, which, coming suddenly on the eye, and again vanishing, in an extremely small portion of time, has been designated a ball of light. Thus, in a thunder-storm which damaged a house at Eastbourne in Sussex, in September 1781, balls of fire were said to dart from the clouds into the sea. These were evidently common electrical sparks seen at a distance; for when the lightning struck the house, 'multitudes saw the meteor dart in a right line over their heads, and all agreed that the form and flame were exactly like that of an immense sky-rocket.'"

The thunder which accompanies a discharge of lightning has been accounted for in various ways, but the most probable conjecture is, that the lightning by its heat produces a partial vacuum in the atmosphere, and that the sudden rushing in of the air from all sides to fill up the empty space causes the particles of air to strike against each other, and thus to produce the sound. The smacking of a whip is a somewhat similar case;

the air divided by the swift motion of the thong and lash rushes together with great rapidity and produces the noise.

The rolling of thunder has been attributed to echoes among the clouds, and that such is the case has been ascertained by observation on the sound of cannon. Under a perfectly clear sky the explosions of cannon are heard single and sharp; but when the sky is overcast, or even when a cloud covers a considerable part of the horizon, they are accompanied with a long-continued roll like thunder, and occasionally a double sound may be heard from a single shot. But there is also another cause for the rolling of thunder, as well as for its sudden and capricious bursts and variations of intensity. It is known that the intensity of a sound is proportional to the quantity of it which reaches the ear in a given time. "Two blows equally loud, at precisely the same distance from the ear, will sound as one of double the intensity; a hundred struck in an instant of time, will sound as one blow a hundred times more intense than if they followed in such slow succession that the ear could appreciate them singly. Now let us conceive two equal flashes of lightning, each four

miles long, both beginning at points equidistant from the hearer, but the one running out in a straight line directly away from him, the other describing an arc of a circle, having him in its centre. Since the velocity of electricity is incomparably greater than that of sound, the thunder may be regarded as originating at one and the same instant in every point of the course of either flash; but it will reach the ear under very different circumstances in the two cases. In that of the circular flash, the sound from every point will arrive at the same instant, and affect the ear as a single explosion of stunning loudness. In that of the rectilinear flash, on the other hand, the sound from the nearest point will arrive sooner than from those at a greater distance; and those from different points will arrive in succession, occupying altogether a time equal to that required by sound to run over four miles, or about twenty seconds. Thus, the same amount of sound is in the latter case distributed over nearly twenty seconds of time, which, in the former, arrives at a single burst; of course, it will have the effect of a long roar, diminishing in intensity as it comes from a greater and greater distance. If the flash be in-

clined in direction, the sound will reach the ear more compactly, (that is, in shorter time from its commencement,) and be proportionally more intense. If (as is almost always the case) the flash be zigzag, and composed of broken, straight, and curved portions, some concave, some convex, to the ear; and if, especially, the principal trunk separates into many branches, each breaking its own way through the air, and each becoming a separate source of thunder, all the varieties of that awful sound are easily accounted for."*

Sometimes the thunder does not begin to be heard till a considerable time after the flash. This arises from the very great difference in the rates at which light and sound travel, for there is no doubt that the lightning and the thunder are produced at the same instant. Astronomers have satisfactorily proved that light requires only a second of time to travel 190,000 miles; lightning travels at even a greater speed; but supposing its velocity to be equal to that of light, it would require only one seven thousand six hundredth part of a second to travel twenty-five miles; an eleva-

* Herschel, Treatise on Sound.

tion far greater than that at which thunder and lightning are produced in our atmosphere. This minute fraction of a second required for the light to travel to the eye of an observer may therefore be entirely disregarded, and no error is likely to arise if we consider that we see the lightning at the very moment of the flash.

The motion of sound, however, is exceedingly slow, compared with that of light, it being not more than about 1,090 feet in a second of time; so that if the cloud whence the lightning has issued be at a distance in a straight line of 1,090 feet, an entire second will elapse between the appearance of the light and the arrival of the sound.

A distance of 2,180 feet will correspond to an interval of	2	seconds
3,270	3	—
4,360	4	—
5,450, or rather more than a mile	5	—

and so on in proportion. Hence, an observer who shall have determined by his watch the number of seconds which elapse between the arrival of the flash and that of the thunder, may easily tell the distance of the thunder-cloud. He has only to

multiply the number of seconds by 1,090 feet, and the product will be the distance required; dividing this product by 5,280, will give the distance in miles.*

Observations of this kind would be useful in determining the height of thunder-clouds, and would also settle the long disputed question of ascending lightning, that is to say, of lightning which is supposed to ascend from the earth itself, or from a cloud formed near its surface. It would also settle another interesting point as to the greatest distance to which the sound of thunder extends. De l'Isle once reckoned 72 seconds between the lightning and the thunder, which, multiplied by 1,090, gives for the distance of the thunder-cloud nearly 15 miles. Another observer reckoned 49 seconds, which gives a distance of about 10 miles. These are the greatest distances at which thunder has ever been heard, which is remarkable when it is considered that the noise of

* It will be borne in mind that the elevation thus ascertained is not usually the vertical height of the cloud, but its distance from the observer measured upon a line inclined to the horizon. In order to ascertain the vertical height of the cloud, its angular height must be measured by a theodolite, or some such instrument.

cannon has been heard at distances varying from 50 to nearly 100 miles.

But lightning is not at all times accompanied by thunder. The broad sheets or flashes which may often be observed in serene nights of summer do not produce any noise of thunder. This *summer lightning*, as it is called, has caused much discussion among scientific men. It is remarkable, however, that Seneca gives what appears to be the correct interpretation of this phenomenon. "In the calmest nights," he says, "with the stars shining bright, you may see lightnings flash; but doubt not that, in the direction of the lightning, there will be found clouds, which the spherical form of the earth hides from our view. The flash ascends on high, and appears in the bright and serene sky, being withal elaborated in some obscure and dark cloud." This view of the origin of summer lightning was revived in 1726 by De Fesc, who combated the opinion then entertained that this was a peculiar kind of lightning, distinct from that which produces thunder. According to him, summer lightning is the reflection in the upper regions of the atmosphere of common lightning, having its origin in a storm of which the

direct view is obstructed by the rotundity of the earth.

It is owing to this reflecting power of the atmosphere that we enjoy the twilight so long before the sun rises and after it has set; but is this reflecting power, it has been asked, sufficient to transmit to the earth the comparatively feeble illumination of lightning? M. Arago gives a very satisfactory reply to this objection. He says:— In the year 1739 during the course of the experiments which Cassini and Lacaille were making upon the velocity of sound, the light in the atmosphere produced by the discharge of a cannon near the lighthouse of Cette was apparent, when the observers were situated in stations from which the town and the lighthouse were entirely obscured by intermediate objects. Again, in the year 1803 M. de Zach used signals on the Brocken mountains in the Hartz, for determining the differences in the longitudes, when it was found that observers placed upon the mountain Kenlenberg, at a distance of more than sixty leagues, saw the flash from the explosion of six or seven ounces of powder in the open air, and this when the Brocken, on account of the rotundity of the earth, was quite

invisible from the Kenlenberg. M. Arago also gives a case from his own experience:—When the guns of the lower battery at the Hotel des Invalides at Paris are fired, an observer placed in the walks of the garden of the Luxembourg, in a spot whence neither the body of the building nor even the dome of the hospital can be seen, may still perceive in the sky, at the moment of discharge, a flash which extends to the zenith,* and even beyond it. If, then, he adds, the comparatively feeble light resulting from the firing of a few ounces of powder is so evidently reflected in the atmosphere, what may not be anticipated from the reflection of the infinitely more vivid flash of lightning?

But a still more satisfactory proof of the accuracy of the above explanation has been given. In the year 1783, in the night between the 10th and 11th of July, Saussure was an inmate at the Hospice du Grimsel. The sky was peculiarly calm and serene; nevertheless, when he cast his eye towards Geneva, he perceived in the horizon several bands of clouds, whence flashes of lightning

* The *zenith* is a point in the sky exactly over the head of the observer.

issued, but no thunder was heard. He afterwards learned that at the very time he was observing the lightning a most tremendous thunder-storm was raging at Geneva. A similar observation was made by Mr. Luke Howard at Tottenham, on the 31st July, 1813, when some trifling flashes of sheet lightning were seen in the distant horizon towards the south-east; the sky was bespangled with stars, and not a cloud was to be seen. Soon after this, Mr. Howard learned from his brother in the south-east corner of England, that on that same 31st of July, at the very time the silent lightnings were seen at Tottenham, there raged at Hastings a dreadful storm, which also extended over France as far as from Dunkirk to Calais.

But if lightning is sometimes seen without its usual noisy accompaniment, thunder is also sometimes heard without the lightning being visible. M. Arago imagines a case of this kind. Suppose there are two distinct strata of clouds, one above the other; suppose the upper stratum to become the centre of a great storm, that it is furrowed by brilliant lightning, and gives out many loud resounding thunders. If the lower stratum of clouds is very opaque or very thick,

the lightning's glare, however vivid, will not be able to traverse it; nearly the whole of it will be absorbed, and no visible portion of it will reach the surface of the earth; whilst, at the same time, as bodies through which light cannot pass allow a free passage for sound, the same individual who distinctly hears the thunder may see nothing of the lightning.

But it is stated, that thunder may occasionally be heard on serene and cloudless days. An accurate observer, quoted by M. Arago, being at Pontchartrain near Versailles, heard very distinctly four or five peals of thunder. He looked carefully around him, but could perceive no cloud, either above or near the earth. Now, if these five peals of thunder did not originate in the clear sky, they must have proceeded from clouds below the horizon, and there is no doubt the latter was the case, since an hour after the thunder was heard, the sky was covered at Pontchartrain with majestic hail-clouds. Whenever thunder is heard with a serene sky, we ought therefore carefully to examine all round for clouds beginning to appear in the horizon.

There is another description of *noiseless light-*

ning, if such it may be called, which appears as a luminous glow upon pointed bodies, such as the masts of ships, the points of spears, &c. It is known to the French and Spaniards under the name of *St. Elmo's* or *St. Helmo's Fires*, and to the Italians, as the *fires of St. Peter and St. Nicholas*. The Portuguese call them *Corpo Santos*, which the English sailors seem to have corrupted into *Comazants*.

One of the earliest notices of this phenomenon is recorded in the "Commentaries of Cæsar," in his book "De Bello Africano:"—

"In the month of February, about the second watch of the night, there suddenly arose a thick cloud, followed by a shower of hail; and the same night the points of the spears belonging to the fifth legion seemed to take fire." Seneca, also, in his "Quæstiones Naturales," states, that a star settled on the lance of Gylippus as he was sailing to Syracuse. Pliny, in his second book of Natural History, calls these appearances *stars*, and says that they settle not only upon the masts and other parts of ships, but also upon men's heads.—"Stars make their appearance both at land and sea. I have seen a light in that form on

the spears of soldiers keeping watch by night upon the ramparts. They are seen also on the sail-yards, and other parts of ships, making an audible sound, and frequently changing their places. *Two* of these lights forebode good weather and a prosperous voyage, and extinguish *one* that appears single, and with a threatening aspect. This the sailors call *Helen*, and the two they call *Castor and Pollux*, and invoke them as gods. These lights do sometimes, about evening, rest on men's heads, and are a great and good omen. But these are among the awful mysteries of nature." Livy also (c. 32) relates that the spears of some soldiers in Sicily, and a walking-stick which a horseman in Sardinia held in his hand, seemed to be on fire.

The auspicious view with which the ancients regarded these appearances was continued by the moderns, modified, however, by the peculiar superstitions of the times.

In the record of the second voyage of Columbus, written by his son, occurs the following passage:—

"During the night of Saturday (October 1493) the thunder and rain being very violent, Saint Elmo appeared on the topgallant-mast with seven lighted tapers; that is to say, we saw those fires

which the sailors believe to proceed from the body of the saint. Immediately all on board began to sing litanies and thanksgivings, for the sailors hold it for certain that as soon as St. Elmo appears, the danger of the tempest is over. But, however this may be," &c. Herrera also notices that Magellan's sailors had the same superstitions.

A far more matter-of-fact account of the phenomenon is related in the memoirs of the Count de Forbin. This navigator, sailing among the Balearic Islands in 1696, states, that during the night a sudden darkness came on, accompanied by fearful lightning and thunder. All the sails were furled, and preparations were made for the storm. "We saw more than thirty St. Elmo's fires. There was one playing upon the vane of the mainmast, more than a foot and a half high. I sent a man up *to bring it down*. When he was aloft he cried out that it made a noise like wetted gunpowder in burning. I told him to take off the vane and come down; but scarcely had he removed it from its place when the fire quitted it and re-appeared at the end of the mast without any possibility of removing it. It remained for a long time, and gradually went out."

This homely description of the phenomenon agrees very well with the accounts of more recent observers. Lieutenant Milne, R.N. in a communication to Professor Jameson's "Edinburgh Philosophical Journal," states, that according to his experience on board ship, St. Elmo's fire usually appears on metal, such as iron bolts and copper spindles; but that on one occasion he noticed it on a spindle of hard wood from which the copper had been removed. He noticed that bad weather always followed the phenomenon.*

On one occasion, in September 1827, he was off the coast of Brazil; the day had been sultry, and heavily charged clouds had been collecting in the S.W. As evening approached it became very dark; the lightning was very vivid, and was followed by heavy peals of distant thunder. About ten o'clock a light was observed on the extremity of the vane-staff at the mast-head, and shortly afterwards another on the weather side of the fore-topsail-yard. One of the midshipmen, curious to

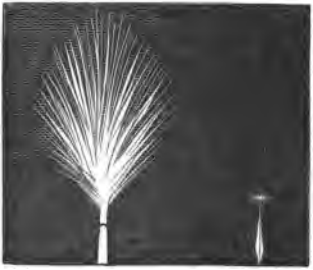
* This remark does not agree with experience. St. Elmo's fire may and often does appear after a storm, and is the harbinger of fair weather. Such appears to have been the belief of Columbus's sailors.

examine this appearance a little more closely, went aloft. He found that it appeared to proceed from an iron bolt in the yard-arm; its size was rather larger than that of a walnut, and it had a faint yellow cast in the centre, approaching to blue on the external edge. On applying his hand to it, it made a noise like the burning of a port-fire, emitting at the same time a *dense smoke* without any sensible smell.* On taking away his hand it resumed its former appearance, but when he applied the sleeve of his wet jacket, it ran up it, and immediately became extinguished, and did not appear again. The light on the vane-staff retained its position for upwards of an hour, but on account of the heavy rain, and probably also from having been struck by the vane attached to the staff, it went out, but resumed its position after the rain had ceased, although with a less degree of brightness.

These appearances depend upon the peculiar action of pointed bodies upon the highly electrified particles of air, and from which lightning con-

* It is not easy to account for this part of the description, except on the supposition that the young observer, naturally associating *smoke* with an appearance so much resembling *flame*, *fancied* he saw the one accompanying the other.

ductors derive a great part of their value. The electrical condition of the particles of air at the upper extremity of the rod, or at the point of a ship's mast, &c., becomes so highly exalted that these particles discharge themselves upon the particles immediately above them, the electrical condition of which is less intense. "The consequence of this is, a luminous brush of beautifully coloured light, attended by a sort of roaring noise.



This brush discharge may be considered as taking place between a good and bad conductor: it is, in fact, an intermitting series of electrical sparks between metal and air, but in such rapid succession as to convey the idea of a continuous stream. The discharge in this case always commences at

the root of the brush, and is complete at the point of the rod before the more distant particles attain the same intensity: hence the discharge is progressive, and occupies a sensible time."* Sometimes the appearance of the *brush* is changed into that of a *star*, especially when proceeding from negative or resinous electricity; in which case the discharge is *towards* the pointed conductor, and not *from* it, as in the case of the brush discharge.

There is another kind of discharge, called the *glow discharge*, in which a metallic rod in contact with air which is becoming rapidly charged, is covered with a beautiful glow of lambent light. The beauty of this effect is greatly increased either by diminishing the atmospheric pressure, or by augmenting the electrical force. Faraday produced on a brass ball within the exhausted receiver of an air-pump, a glow of light over a surface of two inches. The glow came over the ball, and gradually increased in brightness, until it was at last very luminous, and stood up like a low flame of half an inch or more in length.

When a powerful electrical machine is being worked in a room, the air is thrown into the state

* Harris.

favourable for the production of St. Elmo's fire; and accordingly, any projecting sharp points about the room may be seen in the dark tipped with light. Although this phenomenon is usually associated with the masts of ships, it must not be supposed that its action is thus limited. It has been seen on the points of spears, as already noticed; on the tops of steeples and other elevated summits of a city; and during a snow-storm, when much electricity is set free, branches of trees have exhibited a faint bluish light. In January, 1824, after a storm, M. Maxadorf noticed in a field near Cothen, a cart-load of straw, situated immediately under a large black cloud; the extremities of the straw appeared to be on fire, and the carter's whip was also luminous. This phenomenon lasted about ten minutes, and disappeared as the black cloud was blown away by the wind. It is also stated by Rozet, that while some French artillery officers at Algiers were walking on the terrace of a fort on the 8th of May, 1831, after sunset, during a storm, their heads being uncovered, they were surprised to see that each one's hair stood on end, and that each hair was terminated by a minute luminous tuft; on raising their hands, these tufts appeared

also at the extremities of the fingers. Another example from the same locality is interesting. An officer of the Algerian army states that during a violent storm on the 25th of September, 1840, he observed that the arms of the men, when piled in stands, exhibited no symptoms of the electric fluid playing about them; but when the men carried them, the points of the bayonets were strongly luminous, not, however, giving out any sparks. The drops of rain that fell during the storm on the beards and moustachios of the men, remained hanging from them in a state of phosphorescence. When the hair was wiped, the phenomenon ceased, but was renewed the moment any fresh drops fell on it.

Professor Forbes describes the curious effects produced by a similar state of the atmosphere near Mont Cervin. The atmosphere was very turbid, the ground was covered with half-melted snow, and some hail began to fall. "We were perhaps 1,500 feet below the Col, or still above 9,000 above the sea, when I noticed a curious sound, which seemed to proceed from the Alpine pole with which I was walking. I asked the guide next me whether he heard it, and what he

thought it was. The members of that fraternity are very hard pushed indeed, when they have not an answer for any emergency. He therefore replied, with great coolness, that the rustling of the stick no doubt proceeded from a worm eating the wood in the interior! This answer did not appear to me satisfactory, and I therefore reversed the stick, so that the point was now uppermost. The worm was already at the other end! I next held my hand above my head, and my fingers yielded a fizzing sound. There could be but one explanation—we were so near a thunder-cloud as to be highly electrified by induction. I soon perceived that all the angular stones were hissing round us, like points near a powerful electrical machine. I told my companions of our situation, and begged the guide to lower his umbrella, which he had now resumed, and hoisted against the hail-shower, and whose gay brass point was likely to become the *paratonnerre** of the party. The words were scarcely out of my mouth when a clap of thunder, unaccompanied by lightning, justified my precaution."

* The French word for a lightning conductor.

TREE STRUCK BY LIGHTNING.

CHAPTER V.

EFFECTS OF LIGHTNING—ODOUR OF SULPHUR—CHEMICAL CHANGES—FUSION OF METALS—VITRIFICATIONS AND LIGHTNING TUBES—MECHANICAL EFFECTS—TREES AND MASTS STRUCK BY LIGHTNING—MAGNETIC EFFECTS—ACTION OF LIGHTNING ON SHIPS' COMPASSES—ACTION OF LIGHTNING ON A MIXED SYSTEM OF GOOD AND BAD CONDUCTORS—BUILDINGS AND CHURCHES STRUCK BY LIGHTNING—DETAILED ACCOUNT OF DAMAGE DONE TO ST. BRIDE'S AND ST. MARTIN'S CHURCHES, LONDON; TO ST. GEORGE'S CHURCH, LEICESTER; AND TO WELTON CHURCH, LINCOLNSHIRE.

DISCHARGES of lightning through various bodies give rise to a variety of remarkable effects, which seem to have but little connexion with each other. Some of these effects have been already mentioned and illustrated, and others remain to be noticed.

I. *Odour of Sulphur.*—It is a matter of common observation, that a heavy discharge of lightning is succeeded by a suffocating odour, similar to that of burning sulphur. This is especially the case where the discharge has exploded in a confined space, such as a house, or between the decks of a

ship. In the case of the *New York* packet, already noticed, the cabins were filled with a thick sulphureous smoke, which, after the second discharge, was so thick in the ladies' cabin that objects could not be seen through it. So, also, in the case of the *Montague*, it is said of this odour, that "the ship seemed to be nothing but sulphur." On the 31st December, 1778, at 3 P.M. the *Atlas* East Indiaman, lying in the Thames, was struck by lightning, which killed a sailor in the rigging. The ship for a moment seemed to be on fire, but, in fact, received no sensible damage. A strong sulphureous odour was, however, diffused through it, which continued during the day and the next night. On the 18th February, 1770, the church of St. Kevern, in Cornwall, was struck with lightning during divine service, when the whole congregation became senseless. The church was filled with a suffocating sulphureous odour. On the 18th July, 1767, lightning passed down the flues of six chimneys of a house in Paris, diffusing through the house a suffocating odour.

Other cases are recorded in which this smell of burning sulphur has been noticed in the open air during a thunder-storm. Thus, in Dampier's

voyages, it is stated by Wafer, a surgeon, that in a thunder-storm on the Isthmus of Darien the air was infected with a sulphureous odour so strong as to check respiration, especially in the woods. The same observer states that, on another occasion, while crossing a hill after sun-set, he was overtaken by a terrible storm, in which the lightning was attended by an odour of sulphur so intense that the travellers were nearly suffocated by it.

In addition to this testimony it may be stated, that masses of sulphur have actually been found on the ground after a thunder-storm. In a communication to the Royal Society, dated Newport, Isle of Wight, July 9, 1733, Mr. Benjamin Cook, F.R.S., states, that after a night of almost continual lightning, accompanied with very loud claps of thunder, a husbandman found in a meadow near the sea-shore, far from any house, a beautiful yel-

low ball lying on the turf, having a very strong smell of sulphur. It was frosted all over with an efflorescence of fine, shining, yellowish crystals,

which fell off at the slightest touch. On one side was a deep hole, large enough to admit the end of a middle-sized knitting-needle, and in the opposite side a deep depression. Several other small holes were scattered over its surface. The ball was nearly an inch in diameter, and its weight 108 grains. The solid portion seemed to be more compact than the common roll brimstone of the shops, and it burned with a whiter flame.

It is not easy, in the present state of electrical science, to account for the sulphureous odour above noticed. It is, however, a well-known property of the electrical discharge, "to drag into its path light conducting substances, which can facilitate its progress, and by which it is enabled to strike through distances considerably greater than would otherwise be traversed. Thus traces of smoke, free vapour, or any other conducting matter floating in the air, will frequently determine the course of lightning; and not only determine it as to direction, but greatly modify its appearance. A heated or whirling column of air, such as is sometimes seen to arise even in a tranquil state of the weather, would produce a similar effect through its interior and rarefied portion;

and there is little doubt that conducting matter, when dragged into the path of lightning, would be intensely heated and decomposed."*

Although most observers have compared the odour of the electric discharge to that of burning sulphur, some have supposed it to resemble the odour of phosphorus, and others that of nitrous acid. Dr. Faraday is of opinion that the odour is due to the formation of this acid, but M. Schönbein traces it to the formation of a new substance, which he calls *Ozone*.

II. *Chemical changes.*—Lightning produces certain chemical changes in the atmosphere, by converting a portion of the two gases, oxygen and nitrogen, of which it is principally composed, into nitric acid, or aquafortis. It was proved, long since, by Cavendish, that this powerful acid could be formed by passing artificial electrical discharges through a confined portion of air; and Liebig has recently shown that in seventeen specimens of rain-water, collected during or immediately after thunder-storms, all contained nitric acid in greater or less quantities, in combination with lime, or

* Harris.

with ammonia. Out of sixty specimens collected during ordinary rains, these substances were not found in fifty-eight, and the other two exhibited only a mere trace of nitric acid.

III. *Fusion of metals.*—The property of lightning in fusing metals has been already noticed incidentally. A few more instances will be interesting in a chapter intended to illustrate the effects of lightning.

On the 20th April, 1807, at Great Marton, in Lancashire, a windmill was struck by lightning, which, having passed along an iron chain, softened the links, so that by their own weight they became welded together, and the chain was converted into a rod of iron. In June, 1829, a similar occurrence took place at a windmill at Toothill, in Essex. In 1754, at Newbury, in the United States, the steeple of a church was struck by lightning, after which it was examined by Franklin, who found that the lightning had passed along an iron wire twenty feet long, and about the thickness of a knitting-needle, which it reduced to smoke. The course of the wire along the walls and floors was marked by a black line, like that

left after the firing of a train of gunpowder. Another wire in the same tower, of the thickness of a goose-quill, transmitted the lightning without being fused. A house in Westminster, which had been struck by lightning, was examined by Faraday, who states that the discharge passed down the bell-wires and destroyed them entirely, leaving the oxides which resulted from the combustion impressed upon the walls of the room in bands eight or nine feet wide.

In all the foregoing cases it will be observed that the metal chain, rod, wires, &c. were not of sufficient size to convey away the charge of lightning; but, being delayed in its progress, the astonishing heating power of the electric fluid had sufficient time allowed to fuse or to burn away the combustible metal. According to Harris, a copper rod of three-fourths of an inch in diameter, or an equal quantity of copper under any other form, would be sufficient to withstand the heating effect of any discharge of lightning whose destructive influence has ever been recorded.

IV. *Vitrifications and lightning tubes.*—Several travellers have noticed on the summits of high

mountains certain appearances of *vitrification*, or the conversion, by heat, of the surface of the stone into a kind of glass or enamel. These phenomena are supposed to have been produced by lightning, and the conjecture is supported by such facts as the following:—

On the 3d July, 1725, at Mixbury, in Northamptonshire, lightning killed a shepherd and five sheep in an open field. Close to the body of the man were found two holes, five inches in diameter, and forty inches deep. Near the bottom of one of them was a very hard stone, ten inches long, six inches broad, and four inches thick. The surface of this stone was vitrified. In the year 1750 lightning struck a tower at Bologna. Beccaria, who examined it, found a brick at the place where the lightning struck, covered with a greenish transparent glass, which evidently proceeded from the vitrification of a thin layer of mortar which covered the brick. On the 3d September, 1789, lightning struck an oak in the park of Lord Aylesford, at Packington, and killed a man who had sought shelter under it. This man held a walking-stick, which seems to have conducted the lightning to the ground, for at its point was found

a hole five inches in depth, and two-and-a-half inches in diameter. Dr. Withering, who examined this hole a few minutes after the accident, found in it nothing but a few roots of grass burnt by the discharge. And here the observation would probably have terminated had not Lord Aylesford determined to erect a monument on the spot, with an inscription, intended to warn persons against seeking refuge under trees during a thunder-storm. In digging the foundation it was found that the soil had been blackened to the depth of about ten inches. At this depth a root of the tree presented itself: it was quite black; but this blackness was only superficial, and did not extend far along it. About two inches deeper there were evident marks of fusion. Dr. Withering forwarded to the Royal Society an account of this accident, together with several stony masses which had been dug out and exhibited marks of fusion. Among these was a quartz pebble, one corner of which had been completely fused: also a mass of sand agglutinated by the heat; in this mass was a hollow part, where the fusion had been so perfect that the siliceous matter had flowed the whole length of the cavity, and presented, at its termination, a globular form.

Vitrified tubes of sand, of very large dimensions, have been found in various parts of the world in sand-hills. They first attracted the notice of scientific men in the year 1711, when they were discovered by Herman, the pastor of Massel, in Silesia. Specimens of them are still preserved in the mineralogical museum at Dresden. In 1805 they were again noticed by Dr. Hentzen, who found them in Paderborn, and was the first to point out their true origin. Since that time they have been found in various places, and, among others, at Drigg, in Cumberland. The following account of them at the latter place is abridged from the Transactions of the Geological Society for 1812:—

Between the mouth of the river Irt and the sea, near Drigg, in Cumberland, there were discovered, in 1812, in a sand-hill forty feet above the sea level, three hollow tubes, of a vitreous substance, rising perpendicularly above the surface. The sand was dug away round one of these tubes, to the depth of fifteen feet, and, subsequently, to the depth of twenty-nine feet, where a bed of pebbles intervened. Here the tube came in contact with a fragment of hornstone porphyry, glanced off

from it at an angle making about 45° with the horizon, and then returned to its former vertical position. Below this the tube became extremely delicate, and was frequently broken; and at the distance of a foot the sand fell in and prevented further investigation. The tube tapered in its descent, being at the surface one inch and a half in diameter, and at the bottom of the excavation only half an inch. Small lateral branches, two or three inches long, proceeded from different parts of the stem; these were not more than a quarter of an inch in diameter. They were hollow, conical, and ended in points, gradually bending downwards.

The sides of these curious tubes were very hard and rigid, and were coated outwardly with black and white particles of sand, mixed together, and rounded as if by incipient fusion. The

rough and uneven outer surface, which sometimes presented deep furrows, like the bark of a tree, formed a striking contrast with the inner surface of the tube, where there was no longer any appearance of sand, but a whitish or limpid vitrified matter, covered with a smooth glaze. This substance was hard enough to scratch glass. The whole tube had the appearance of being creased by compression while in a solid state, and thus the tube was sometimes so flattened as to be entirely closed. On touching the pebble above-noticed, the tube was welded to it, but, on the side adjacent to the pebble, the substance of the tube was wanting, and in place of it an unglazed rust-coloured mark, passing across the flat face of the stone, and having minute particles of glass attached to certain parts.

After various experiments on the sand of these hillocks, made with a view to ascertain the cause of the phenomenon, it was found that the substance of these tubes could be imitated, in some degree, by subjecting the sand to intense heat. The flame of a spirit lamp, urged by a stream of oxygen gas, formed a clear glass from the sand of the hillock; but even thus the fusion was partial,

and the utmost intensity of the flame was required to support it.

That the tubes found in the hillock were very recent was certain, from the shifting nature of the sand; and as they had all the marks of fusion, it seemed evident to the scientific persons who conducted the inquiry, that lightning alone was capable of affording sufficient heat and force to make them.

The sand hillocks of Drigg, though of inconsiderable elevation, are said to be not unfavourably situated for promoting a discharge, since they present themselves as the first and highest object in front of the marshes of the Irt to clouds coming from the sea.

Mr. Darwin has also described similar tubes, discovered by him in South America, in a broad band of sand hillocks, near the river Plata, a few miles from Maldonado. These sand hillocks, not being protected by vegetation, are constantly changing their position; consequently the tubes projected above the surface; and numerous fragments lying near, showed that they had formerly been buried to a greater depth. Four sets entered the sand perpendicularly: by working

with his hands Mr. Darwin traced one of them two feet deep; and some fragments, which had evidently belonged to the same tube, when added to the other part, measured five feet three inches. The diameter of the whole was nearly equal. The internal surface was completely vitrified, glossy, and smooth. A small fragment, examined under the microscope, appeared, from the number of minute entangled air, or perhaps steam bubbles, like an assay fused before the blow-pipe. The sand was entirely or in greater part siliceous; but some points were of a black colour, and from their glossy surface possessed a metallic lustre. The thickness of the wall of the tube varied from a thirtieth to a twentieth of an inch, and occasionally even equalled a tenth. On the outside, the grains of sand were rounded, and had a slightly glazed appearance. The tubes were generally compressed, and had deep longitudinal furrows, so as closely to resemble a shrivelled vegetable stalk, or the bark of the elm or cork tree. Their circumference was about two inches, but in some fragments, which were cylindrical and without any furrows, it was four inches. The compression from the surrounding

loose sand acting while the tube was still softened from the effects of the intense heat, had evidently caused the creases or furrows. Judging from the uncompressed fragments, Mr. Darwin thinks the *measure* or *bore of the lightning* (if such a term may be used) must have been about one inch and a quarter.

Attempts have been made to produce these tubes by means of a powerful electrical battery passed through finely powdered glass. A tube produced in this way was nearly an inch long, with an external diameter varying from an eighth to a tenth of an inch, with an internal diameter of about the twenty-fifth of an inch. The attempts failed with powdered felspar and quartz: and yet such is the wonderful power of lightning, that it has formed tubes thirty feet long, and in the uncompressed part full an inch and a half in diameter, and this in so refractory a substance as quartz.

It appears also that several tubes are produced by one stroke, the lightning apparently dividing itself into separate branches shortly before entering the ground.

In order to render it quite certain that lightning is the agent employed in the production of these

tubes, an example was wanting in which lightning was actually seen to strike the ground in which these tubes were afterwards found. Such a case has been given by Dr. Fiedler. On the 13th July, 1823, lightning struck a birch-tree near the village of Rauschen, on the shores of the Baltic, and at the same time set fire to a juniper-bush. Some people ran to the spot, and found near the tree two narrow and deep holes. One of them, notwithstanding the cooling effect of the rain which was falling, was hot to the touch. Professor Hagen, of Königsberg, caused the earth about the holes to be carefully removed, and at the depth of about fifteen inches a vitrified tube commenced, which bore the same characters as in those already noticed.

V. *Mechanical Effects.*—When lightning strikes solid bodies which are imperfect conductors, it tears them to pieces, and scatters huge fragments to a great distance, just as if a powerful explosive force were suddenly generated within them. In fact, if a quantity of gunpowder were concealed within a solid substance and fired, the effects of the explosion would resemble those of lightning.

A few examples will show this. On the night between the 14th and 15th of April, 1718, the church of Gouesnon, near Brest, was struck by lightning with such force that it shook as if by an earthquake. The stones of the walls were projected *in all directions* to a distance of from fifty to sixty yards. In January, 1762, lightning struck the church of Breag, in Cornwall, and destroyed the south-west pinnacle of the tower. A stone weighing 170 lbs. was projected from the roof of the church to a distance of sixty yards in a *southern* direction. Another fragment of stone was projected to the *north*, to a distance of four hundred yards. A third was projected to the *south-west*. On the 6th August, 1809, at two o'clock P.M. at Swinton, near Manchester, lightning struck the house of Mr. Chadwick. The house was immediately filled with a sulphurous vapour. The external wall of a building erected against the house as a coal-shed was torn from its foundations, raised in a mass, and conveyed to a distance varying between nine feet at one end and four feet at the other. It maintained its erect position for some distance. This wall was eleven feet high, three feet thick, and its founda-

tion was about a foot below the ground. It was composed of 7,000 bricks, which (without reckoning the mortar by which they were held together) would have weighed about twenty-six tons. Above this coal-shed was a cistern, which at the time of the occurrence contained a quantity of water, and the shed contained about a ton of coals.

The explosive force of lightning has been explained by an ingenious theory by M. Arago. The heating power of the electric fluid has been already illustrated, by which it was seen that the discharge of an electric battery or a stroke of lightning is sufficient to melt, burn away, or make red-hot, a wire or rod of metal, according to its thickness and the force of the discharge. If water be heated to a very much lower temperature than is required to make iron red-hot, say to 500° Fahr., steam would be generated with a pressure of 675 lbs. on the square inch. Now, M. Arago supposes that when a badly conducting solid is struck by lightning, the moisture contained in it becomes suddenly converted into high-pressure steam, the elastic force of which rends it to pieces, and scatters it in all directions. "If we suppose moisture in the fissures and cells

of common building stone struck by lightning, the sudden development of steam would break it, and the fragments would be projected to a distance in all directions. Under the same circumstances, the sudden transformation into a highly elastic vapour of the water mingled with the strata on which the foundations of a dwelling-house repose, will be sufficient to uplift the entire edifice, and transport it, as has actually been done, to a considerable distance."

The singular tearing into shreds which wood undergoes when it has been penetrated by lightning, certainly indicates the presence of some powerfully expansive force. For example, in the year 1676 a flash of lightning struck the abbey of St. Médard de Soissons, and its effects on some of the rafters of the roof are thus described by an eye-witness:—"Some of them were found divided from top to bottom, to the depth of three feet, into the form of very thin laths; others of the same dimensions were broken up into long and fine matches; and some were divided into such delicate fibres, that they almost resembled a worn-out broom." The effects of lightning upon green wood are equally remarkable,

On the 27th June, 1756, at the abbey of Val, near the island Adam, the lightning struck a large solitary oak, fifty-two feet high, and somewhat more than four feet in diameter at its base. The trunk was entirely stripped of its bark, which was found dispersed in small fragments *all round the tree* to the distance of thirty or forty paces. The trunk, to within about two yards of the ground, was cleft into portions almost as thin as laths. The branches were still connected with the trunk, but they, too, were deprived of every particle of bark, and had been subjected to a most remarkable slicing. The trunk, branches, leaves, and bark, did not exhibit any trace of combustion, only they appeared completely dried up and withered. On the 20th July of the same year, lightning struck a large oak in the forest of Rambouillet. On this occasion the branches were totally separated from the trunk, and dispersed around with a certain degree of regularity. They did not appear to be withered, and their bark seemed sound. The trunk itself had not been pealed clean, but, like the oak of the island Adam, it had become a mere bundle of laths; there was also this difference, they extended to the very

ground instead of the process being arrested at a certain height. A somewhat similar case is related by Mr. Jesse of the effect of lightning on a fine large thriving oak in Richmond-park. All the main branches had been carried away, one large limb being sixty paces from the tree. The tree itself, which might have contained from two to three loads of timber, was split in two, and the bark so completely stripped from it, that on removing the turf which surrounded the butt of the tree, the bark had disappeared even below the surface of the ground. Not one of the small shoots or branches could be found, but the ground was strewed with a quantity of black brittle substances, which pulverized in the hand on being taken up. The tree was standing near some others which were uninjured. A person who was near at the time stated that the noise and crash were tremendous, and that the destruction of the tree was instantaneous. In another case, described by Professor Munke, the lightning struck an oak, the diameter of which was three feet at the level of the ground. The entire trunk of this great tree disappeared; or, to speak more accurately, the lightning had separated it into shreds

many feet long, and between a line and a line and a half in thickness. Three limbs, from twenty to twenty-four inches in diameter, had fallen vertically, cut clean through as if by a single stroke of a hatchet; they preserved their leaves and branches. Not the slightest trace of burning or blackening was perceived. On the 25th May, 1842, at the village of Adforton, near Ludlow, lightning struck a poplar-tree nearly forty-five feet high; it was shivered to pieces, and the ground for a hundred yards round it thickly covered with splinters, from four to twelve inches long, many of which seemed entirely smashed. The body of the tree was divided into eight or ten large portions, which came away with the branches and fell wide of each other, but all on the south side. None of the fragments or splinters were at all singed or discoloured.* On the 2d March, 1812, H. M. ship *Blake* had the main top-gallant and royal masts shivered by lightning. The top-gallant mast, which had a quantity of green sap in it, was thrown out by the shock into long fibres in all directions. It was stated by Admiral Sir Edward Codrington, who then com-

* See Frontispiece to this chapter, p. 116.

manded the ship, that the mast "looked like a tree with branches." All these remarkable results appear to be the necessary consequence of the action of some elastic force developed between the fibres of the wood; it may be the moisture or the sap of the wood suddenly transformed into steam by means of a flash of lightning, or it may be the expansive force of the air, or some other force the nature of which we are ignorant. Its effects, as exhibited in the foregoing facts, are tremendous, but they appear still more so in the details of damage by lightning at sea, partly because when ships are struck there are many intelligent observers at hand to relate all the particulars, which is not often the case in accidents from lightning occurring on land.

A remarkable instance of the expansive force of lightning occurred in the case of H.M. revenue cruiser *Chichester*, in a storm on the coast of Galway, on the 7th of March, 1840, when the masts and part of the decks and bulwarks were destroyed. A ball of fire, it is said, descended from the mast, and broke through the deck: it knocked down several of the crew, leaving a sensation as if a solid piece of timber had fallen upon them. The com-

mander of the vessel (Captain Stuart) was sitting at dinner in the cabin with his two daughters when the accident occurred. The ball of fire passed over the table, shivering in pieces the whole of the dishes and glasses, without injuring any one. The sky-lights were thrown up, the whole deck in the centre of the vessel raised off the beams, and the patent lights all thrown out. The electric fluid passed through the bottom of the vessel, in many places along the copper bolts, and tore off the copper sheathing* opposite to them and under water. The magnetic attraction of all the compasses was destroyed, and those who had watches found that they had stopped. The vessel was filled with smoke for some time after being struck, and serious fears were entertained of her being on fire. By *fishing* or strengthening the mast the captain was able to take the vessel to Greenock for repair.

We may arrive at something like a measure of the force exerted by lightning on badly or partially

* There is generally some putty over the ends of the bolts, and between them and the copper sheets there is either paper or tarred felt. It has been suggested by the communicator of this case that the sudden expansion of these materials, or of the air between the ends of the bolts and sheathing, may have produced the effects described.

conducting matter by an examination of the effects produced on the large masses of iron and timber which constitute the masts of our large ships.

It may be of interest to observe that the lower mast of a seventy-four gun ship is 122 feet long, about 3 feet 4 inches in diameter; it contains 1,000 cubic feet of timber, and with all its iron-work about it weighs at least 18 tons. The topmast is 70 feet 6 inches long, 1 foot 10 inches in diameter; contains 175 cubic feet of solid timber, generally Riga fir, and weighs about 3½ tons. The top-gallant and royal masts together are 52 feet 6 inches long, and from 12 to 6 inches in diameter. They contain about 20 cubic feet of solid fir timber, and weigh about seven hundredweight. The total length of such a ship from the keel to the truck is about 220 feet.

On such a ship as this (the *Sultan* of 74 guns), a stroke of lightning fell on the 19th September, 1812, at 4 o'clock P.M. when off the north coast of Sardinia. The effects were as follow:—The highest spar or top-gallant and royal mast was fairly shaken in pieces; the next or topmast, 70 feet long, was burst into shreds like a bundle of laths, and stood gaping open in the upper end; it

remained in this condition for some minutes, and then fell with a terrific crash. So complete was the destruction, that the decks of the ship were completely filled with the chips of wreck of more than three tons of wood. The next, or lower mast, weighing 18 tons, was struck through to the very centre; and the lightning made one or two holes in it sufficiently large for a boy to creep into. The chips which were torn out helped to cover the deck. It was with difficulty prevented from falling until the ship got into port, when the mast in its ruined state was taken out. On removing the mouldings and fishes, it literally fell to pieces.

H.M. ship *Desirée* was struck by lightning in the autumn of 1803, at Port Antonio, in Jamaica. Admiral Ross, who commanded the ship, states, that one part of the main-topmast was found on the following morning sticking in the mud on one side of the harbour, and another part in a timber-yard on the opposite side.

In December 1838, H.M. ship *Ròdney* was struck by lightning. The topgallant and royal mast, 53 feet long, weighing nearly 8 hundredweight, entirely disappeared from the ship, with the exception of the end of the royal mast. The sea was covered

with chips and splinters, and, to use the expression of the sailors, "The water alongside looked as if it had received all the refuse of a carpenter's shop."

The iron hoops and other iron work on the main-mast weigh about a ton and a half. The iron hoops which are clasped or driven round the mast are five inches wide and half-an-inch thick; there are about twenty-six of these, which help to bind together the masses of timber forming the mast. Out of these twenty-six immense iron hoops no less than thirteen were broken asunder and came rattling down on the deck with a horrid clang. The ravages of the discharge could be traced through 53 feet. The lightning had also entered the very heart of the mast, which it charred, and at the point where the lightning escaped was a hole many inches deep.

In this case the sailors declare that they saw balls of fire moving about the deck, and that they ran after them to throw them overboard. This must have been a sort of progressive St. Elmo's fire, which frequently accompanies these discharges, as in the following case, where we have also another illustration of the remarkable expansive force developed by lightning. We quote the words of Capt. Fitzroy.

"I was a lieutenant on board the *Thetis* when her foremast was shattered by lightning in Rio harbour, and shall not easily forget the sensation. Some of the officers were sitting in the gun-room one very dark evening, while the heavens were absolutely black, and the air hot and close to an oppressive degree, but not a drop of rain falling, when a rattling crash shook the ship. Some thought several guns had been fired together; others, that an explosion of powder had taken place; but one said, 'The ship is struck by lightning!' and that was the case. The top-gallant-masts were not aloft; but the fore-top-mast was shivered into a mere collection of splinters; the hoops on the fore-mast were burst, and the interior as well as outside of the mast irreparably injured. From the fore-mast the electric fluid seemed to have escaped by some conductor without doing further damage; yet it filled the fore part of the ship with a sulphurous smell, and the men who were there thought something full of gunpowder was blown up. No person received injury; the fore-mast was taken out afterwards, and replaced by another, purchased from the Brazilian government at a great expense, and made by the carpenters of the

Thetis. I should say that the electric fluid shook rather than shattered the fore-top-mast, for it did not fall, but resembled a bundle of long splinters, almost like reeds. It twisted round the head of the foremast, instead of descending by the shortest line, went into the centre of the spar, and then out again to the hoops, every one of which above the deck was burst asunder. The *Thetis* was to have sailed in a few days, but was detained by this accident almost two months. She had no conductor in use.

"Only two or three flashes of lightning were seen afterwards; they were accompanied by loud peals of thunder, and then heavy rain poured down. Just before the rain began, St. Elmo's fire was seen at each yard-arm, and at the mast-head. Those who have not seen this light—always a favourite with sailors, because they say it only appears when the worst part of the storm is over—may excuse my saying that it resembles the light of a small piece of phosphorus; not being so bright, or so small, as that of a glow-worm, nor yet so large as the flame of a small candle. I was curious enough to go out to a yard-arm, and put my hand on a luminous spot, but of

course could feel nothing, and when I moved my hand the spot reappeared."

VI. *Magnetic Effects.*—When lightning explodes upon a ship which is not furnished with conductors capable of carrying it off, the magnetism of the compass needle is disturbed, or entirely destroyed, or the poles of the needle may be reversed. Lightning also renders masses of iron and steel strongly magnetic, which previously exhibited no traces of magnetism. In the case of the *New York* packet struck with lightning, already noticed, nearly all the iron on board was rendered magnetic, even to the steel parts of mathematical instruments and the springs of watches and chronometers. The magnetism of the four compasses on board was either greatly diminished or totally destroyed. The *Orwell*, on a voyage from New Orleans to Liverpool, in February 1838, was struck by lightning and set on fire. With the greatest difficulty, and by throwing much of the cargo overboard, the ship was saved; but the storm continuing, the vessel was again struck by lightning the following day, and this second stroke shivered the main-mast, main-topmast, and main-

top gallant-mast. There were on board two excellent chronometers, and these were so strongly magnetized as to be entirely useless. The steel-work in them would attract and carry small pieces of iron and steel. The compasses, on the contrary, entirely lost their magnetism, and would run round and stop at any point whatever.

The action of lightning upon the compass needle was ascertained for the first time in a curious manner. About the year 1675, two English convoys were proceeding to Barbadoes, and being arrived at the Bermudas, lightning fell upon one of them, destroyed the mast, and tore the sails; the other ship received no injury. The captain of the second ship having remarked that the injured ship had put about and appeared to be steering for England, inquired the cause of this sudden resolution, and was surprised to learn that his companion thought she was pursuing the previous track to the West Indies. A careful examination of the compass of the injured ship showed that the fleur-de-lis of the compass card, instead of pointing to the north, now pointed to the south, or, in other words, the polarity of the needle on board had been reversed, and remained so during the rest of the voyage.

In many cases which have been recorded, the ship's compass, instead of having its poles reversed, has had its magnetism so much disturbed, that instead of pointing north it has pointed west, north-north-west, south-west, &c., thus leading the mariner astray, and often producing lamentable shipwrecks. So, also, by magnetizing the springs of the chronometer, its rate of going is interfered with, and thus, after a few days, serious errors in longitude may occur, and also prove a source of danger to the ship. When the *New York* packet arrived in Liverpool, it was found that the chronometer was 33′ 85,″ or nearly thirty-four minutes in advance of the time which it would have marked if the ship had not been struck by lightning.

It is important to observe that in ships furnished with good conductors, capable of carrying off the whole of the discharge, the compasses have not been affected or damaged.

VII. *Action of Lightning upon a mixed system of good and bad Conductors.*—The reader will be prepared, from many of the details in previous pages, to conclude, that when lightning strikes a system

of good and bad conductors, it spares the former and expends its fury upon the latter. If good conductors, covered with non-conducting substances, lie in the path of the lightning, it will force its way to them and occasion considerable damage. So also, if the lightning traverse a metallic rod too small to transmit the whole of the charge, and a larger conductor be near, the lightning will desert the small rod for the larger one, forcing its way through intervening non-conductors. All these points have been abundantly illustrated by numerous well-authenticated cases, from which our space will allow us only to select a few.

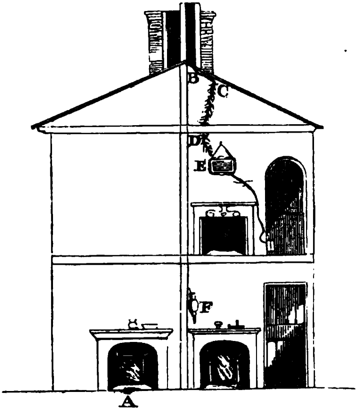
In the year 1754 a discharge of lightning fell upon the tower of Newbury in the United States, completely destroying the upper part, which consisted of an immense pyramid of carpentry about seventy feet high. The lightning then encountered a metallic wire which descended through the tower to a point about twenty feet lower. It fused this wire in several places, but the carpentry surrounding it suffered no damage, although the flash had by no means expended its force, as was proved by its effects in descending lower. Arrived

at the lower extremity of this wire, the lightning again passed through the carpentry, which it damaged considerably, nor was its force yet expended, for on reaching the ground it tore up several of the foundation stones of the building, and scattered them to a considerable distance.

The following curious case will further illustrate the property of lightning in searching out, as it were, for pieces of metal to facilitate its descent:—

On the 7th June, 1789, some houses in Philadelphia, struck with lightning, exhibited curious effects, which will be better understood by referring to the accompanying section of two of the houses. The lightning seems to have been assisted in its descent by the smoke of the two kitchen chimneys, shown in the section, and to have divided upon entering them. The other chimneys, in which no fire was burning, escaped uninjured. The lightning forced out the brick-work on the north side of each down to the roof. It continued down that to the left until it came to the iron hook hanging on the crane, where a woman, who was standing by the fire-side, says she saw it like a large ball of fire. From thence it passed either along the hook or the crane, or probably both,

and entered the hearth at A, close to the back wall, and making a cavity as large as a man's head.



In the right-hand chimney there was but very little fire. The lightning descending it, did some injury to the roof at B, close to the brick-work, then entered the roof at C, and along the surface of the wall to D. Here it entered the chamber, tearing off a portion of the ceiling and plastering of the wall. At E hung a glazed picture with a gilded frame, which was shivered to pieces. The

lightning appears to have passed both ways along the gilding of the frame to the opposite corner; thence it passed along the surface of the wall in a crooked line, about half an inch wide (as appeared by a decided mark of its track), to the upper part of the lower hinge of a closet door. From the bottom of this hinge it seems to have passed by the rivets through to the inside of the closet, and probably by a nail through the floor, brushing off the ceiling and lathing of the closet of the kitchen below. This closet door was broken to pieces, and thrown to a distance by the explosion. From this closet it seems to have dispersed in every direction. No traces of it were found on the walls of the closet, but a number of pewter plates and dishes which were standing on the shelves exhibited signs of fusion where they touched each other. Part of the lightning appears to have passed along the shelf over the fire-place, on which stood a coffee-pot and other kitchen furniture, which was knocked down but not injured. At F a large hand-bellows were suspended by a string on a nail, the back-board of which was split through apparently with great violence. Both the kitchens were filled with smoke, soot, and

ashes by the explosion, but no person was hurt. The woman who saw the ball of fire at the upper end of the pot-hook, is confident that it proceeded upwards. This opinion was probably founded on the explosion of the bricks and earth upwards at A. A young woman who was sitting on the right side of the closet door, within a foot of the shivered part, received no other injury than a slight mark on one foot, with a sense of numbness in both, which disappeared on the following day. From this stack of chimneys in the direction of the storm, that is, southward, there was no lightning-rod, nor any more elevated building for a considerable distance, which might have intercepted the stroke; but immediately to the north and south-east, the adjoining buildings were much higher, and there was one pointed rod at no great distance.*

On the 15th of March, 1773, lightning struck the house of Lord Tilney, at Naples. A large assembly, consisting of about five hundred persons, happened to be in the house at the time, yet no one was injured. De Saussure and Sir William

* Rittenhouse, in the Transactions of the American Philosophical Society, vol. iii.

Hamilton, who were present, made a careful examination of the house next day; they found that almost all the gildings of the rooms, the cornices of the ceilings, the rods supporting the drapery of the furniture, the gilding of chairs and sofas, the gilded frames of the doors, and the bell-cords, were fused, blackened, or scaled off. As usual, the greatest injury was produced in places where conducting matter was interrupted. "It is certain," observes M. Arago, "that lightning sufficiently powerful to fuse wire would kill a man; and yet, in this case, lightning, sufficiently intense to produce death, traversed nine rooms containing five hundred persons, without injuring any one, its course being confined to a series of accidental conductors supplied by the walls and furniture."

The following remarkable case shows that lightning will desert a small conductor for a larger one, forcing its way through intervening non-conductors to get to it. In the house of Mr. Raven in Carolina (United States) lightning struck a large rod of iron placed on the roof; it then passed along a portion of a brass wire which was carried down the outer surface of the wall,

and connected with a bar of metal sunk in the ground. In its descent the lightning fused all that part of the wire which extended from the roof to the first-floor without injuring the wall; but on getting down to the first-floor it took another course; here it deserted the wire, burst through the wall, in which it made a large hole, and entered the kitchen. The cause of this singular deviation at right angles to its former course was evident when it was found that a gun, standing on its stock, rested with its barrel against the kitchen wall exactly at the place where the lightning forced its way through it. The lightning passed along the barrel of the gun without injuring it; the stock, however, was broken, and the hearthstone near it was damaged.

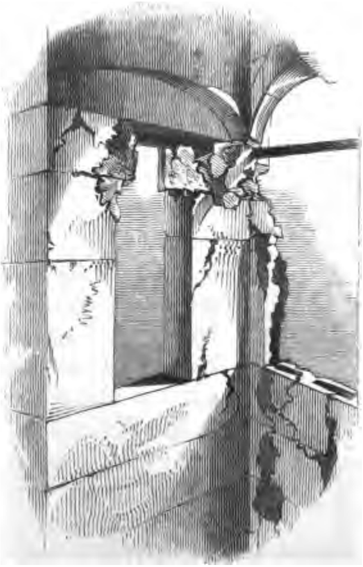
On the 18th of June, 1764, at three o'clock in the afternoon, lightning struck the steeple of St. Bride's church in Fleet-street, London, and did much damage. The spire of this steeple, where it rises above the belfry, is composed of four stories of different orders of architecture, besides the obelisk, which rises immediately over them. The stone piers of these stories are connected together and strengthened by horizontal iron bars. The

obelisk terminates in seven courses of stone, the five upper ones being connected together at top and bottom by iron collars soldered with lead. An iron bar, about twenty feet in length and two inches square, passes through these for about ten feet, and supports the ball and cross, and the vane of gilt copper. To diminish the quantity of stone in this structure, iron cramps are employed in several places, and these are covered with stone ornaments. Other iron bars are also employed to support the tops of the windows; forming altogether a series of metallic bodies separated by badly-conducting stone; and this was rendered even a worse conductor than usual by a considerable period of very warm dry weather which preceded the storm.

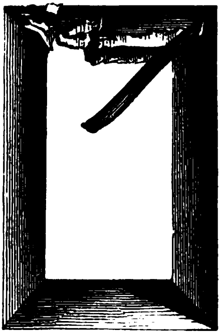
When the lightning struck this steeple, the iron bar supporting the weather-cock conveyed the electricity safely down to its termination;* but here, no longer meeting with a good metallic conductor, the lightning burst with explosive violence; it shattered the stone upon which the

* The gilding on the cross where the lightning first struck was blackened, and the soldering along the bar exhibited marks of fusion.

iron rod rested into many pieces, all of which were displaced, and some of them thrown from the steeple. The centre of the stone upon and near which the iron rod rested was beaten to



powder, and a hole made through the under part of the stone. Through this hole the lightning passed to some iron cramps, before noticed, and threw off large scales of stones at their ends. It then leaped over three courses of stones to a concealed chain, one foot above the base of the obelisk, and two feet above the first cross bar. Here the stones were burst and shattered, and a considerable number of fragments thrown off. The lightning then broke through the roof above the composite story, tore out a large portion of the stone, struck



the iron bars which are placed immediately under and in contact with the stones, broke one of them directly across, and bent the larger part of it from the horizontal direction to an angle of about 45°, as shown in the figure. At the end of one of the iron bars, it threw off the upper part of one of the composite pillars, just above its capital, and a large portion of the cornice projecting over it, with such force, that part of a

stone weighing seventy-two pounds was projected, not only the whole length of the body of the church, but beyond it across St. Bride's-lane, where it fell upon the top of a house, broke through the roof, and lodged in the garret. The horizontal distance from the steeple to the place where it fell, was at least 150 feet; the height from which it fell somewhat more than 200 feet. The shaft of the next pillar was also broken, and a large portion of its diameter thrown down. The Ionic story suffered considerably, one of its pilasters being knocked off. The lower stories were not so much injured. The damage done to the steeple was generally where the ends of the iron bars were inserted into the stone, or placed under it; and in some places, by its violent action on the stone, its course could be traced in a series of leaps from one iron bar to another,

In several places, the ornamental stones covering the iron cramps had been quite blown off and thrown away. A great number of stones, some of large size, were thrown from the steeple, three of which fell upon the roof of the church and greatly injured it: one large stone, breaking through the timbers of the roof, lodged in the gallery of the church.

In the tower of the steeple, in the bell-loft, the lightning struck the south-west window above the bells, not far from an iron bar, and rent out several large stones, (some of which fell into the bell, which was very near this part of the steeple,) and passing below the bell, tore out at another place a great number more. One of the stones torn out above the bell was thrown to the north-east side of the tower. Between the two places in which the lightning had here exerted its fury, the wooden block which confined the axis of the frame of the great bell, and was fastened down with two iron staples, was thrown off, and the staples torn out.

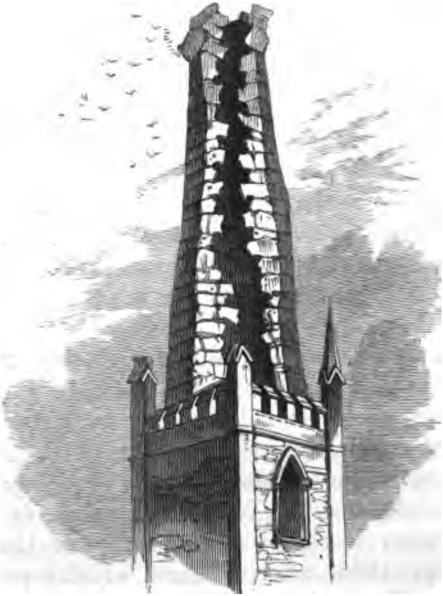
The amount of damage done to this beautiful fabric was so great, that it was found necessary to rebuild 85 feet of the spire. When the scaffolding for this purpose was erected, Dr. Watson carefully surveyed the damaged building, and

communicated to the Royal Society the particulars of the accident. He observes, that his inspection "completely indicated the great danger of insulated masses of metal to buildings from lightning; and, on the contrary, evinced the utility and importance of masses of metal continued and properly conducted, in defending them from its direful effects. The iron and lead employed in this steeple, in order to strengthen and preserve it, did almost occasion its destruction; though, after it was struck by the lightning, had it not been for these materials keeping the remaining parts together, a great part of the steeple must have fallen." *

This sensible advice, although given more than eighty years ago, has not even yet been generally acted on, or we should not have to lament every year the deplorable accidents to our churches from lightning. The following engraving represents the appearance of St. Michael's Church, at Black Rock, near Cork, on the morning of the 30th January, 1836, after a storm of the previous night. The spire was built with limestone, strengthened with iron cramps and bars, as in

* Philosophical Transactions, vol. liv.

the case of St. Bride's. It will be seen that the damage is in a straight line on one side of the

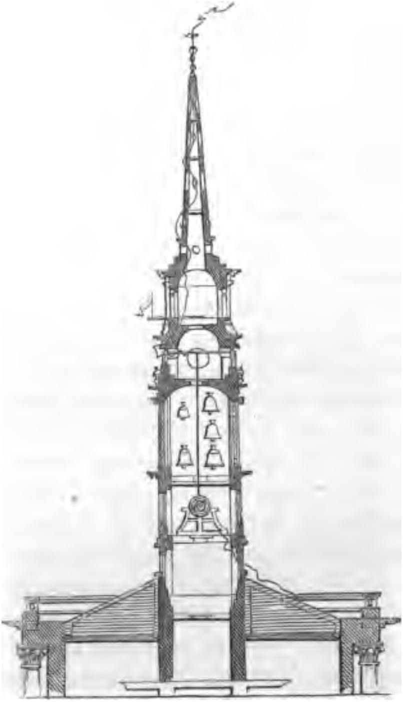


steeple; "this was on the windward side, which probably received the greatest quantity of rain,

and so rendered it the least resisting line, but not of sufficient conductibility to carry off the discharge without damage."

The case of St. Martin's Church, London, struck by lightning on the 28th July, 1842, is also an instructive example of the nature of these discharges. The details of the accident have been collected and commented on by Sir W. Snow Harris, from whose account the following abridged notice of the course taken by the lightning is selected. The section of the tower given on the next page will assist the explanation.

The first point struck was the point of the vane-spindle; the discharge passed into the spire through the iron rod, without any damage to the blocks of stone immediately surrounding it, and without affecting the copper ball or the gilding of the vane. On leaving the vane-rod, the discharge passed into the masonry of the spire, where, in darting from one to another of the iron clamps, it so damaged the spire as to leave the whole in a tottering state. Two blocks of stone were thrown completely out of their places, and fell through the roof into the church, the joints of the spire were all loosened, and its general surface con-



torted. Two other stones were quite dislocated: if these had also been thrown out, the whole of

the upper portion of the spire must have fallen. From the base of the spire the discharge passed with destructive violence on the frame-work of the flagstaff, the wood-work of which was shivered, and then seizing the lead floor of the cupola, it forced a passage to a metal cramp within the masonry, where it tore up and fractured a large flat stone, and turned it completely over; in this way it passed to the nearest points outside the tower leading to the north and west dials: upon these the discharge divided, and fell upon the gilded letters XI. and XII., the gold of which, on the west dial more especially, was burnt up and blackened. From these points it exploded upon the minute-hands, where it also blackened the gold, and damaged the points of the hands. From this, it passed along the spindles of the north and west dials into the dial-room, without affecting the surrounding parts, and seizing the iron rod connecting the spindles with the clock, passed safely within its case of wood, and between the masses of metal in the bells down to the works of the clock: the only traces left in this course were a little fusion of the brass screws and of the iron at the union of the joints. The discharge, on reaching the works

of the clock, melted a small copper wire by which the lever handle key was suspended on the iron frame: it now spread over the wheels and other works, magnetized the steel pivots, blackened the silver face of the regulator, and burst open the door of the outer wooden casing; it did not, however, stop the clock. The discharge, on leaving these conductors, forced a passage through the floor of the clock-room, by the assistance of some metal cramps, into the ringing-chamber, leaving the floor as if blown up by gunpowder. Coming out just over one of the iron window-frames, it shattered all the glass in the window by the violent concussion, and left marks of fusion on small streaks of lead in the joints of the stones. By this course, it reached the lead of the roof, which was slightly fused at the point on which the discharge first fell. After this it became dispersed upon the earth without further damage by the large masses of metal and pipes connecting the roof with the ground.

"It is impossible," says Sir W. Snow Harris, "to conceive a case giving a better insight into the nature of disruptive discharges through an accidental arrangement of good and imperfect con-

ductors. It will be seen, that all the damage occurred in points where good conducting matter ceased to be continued, as, for example, between the termination of the vane-rod and the clock-faces, and again between the works of the clock and the lead of the roof, whilst the course of the discharge is so marked and definite, and so independent of bodies not contributing to assist its progress, that it actually passed down a small iron rod within a few inches of the bells, without affecting in any way these large metallic masses, or disturbing the wooden case by which the rod was surrounded. The discharge, in passing upon the dials, selected the north and west faces as affording the easiest line of transit: as the minute hands only could contribute to the conduction, being at the time in a position to transmit it to the centre of the dial, these only were affected; the hour hands, although continuous to the lower part of the dials, were evidently beyond the line of action: the course of the discharge, therefore, became diverted at right angles nearly from the line of the hands, in order to pass upon the line of metals within the tower. In this, as in all other instances of damage to buildings or ships by light-

ning, the course of the electrical discharge is similarly determined through points which offer the least resistance to its progress, and the damage invariably occurs between detached masses of metal."

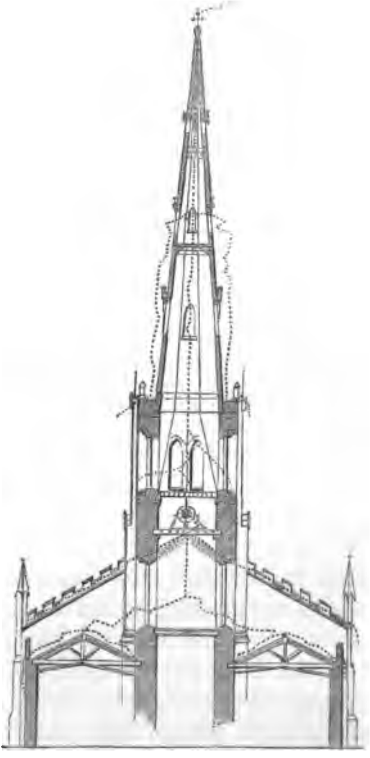
A recent and very striking instance of damage done to churches by lightning presents itself in the case of St. George's Church, Leicester, a modern and very beautiful edifice, first opened for divine service in February 1827. The architect of this building, William Parsons, Esq., has kindly furnished the writer with full particulars of the disaster, and with drawings illustrative of the very serious damage done to the church. The storm which ushered in the catastrophe was more violent and extensive than is often experienced in this country. It occurred on the 1st of August, 1846. At two in the morning of that day it had visited the Channel Islands; it then raged violently in the neighbourhood of London and throughout the south-eastern counties; and at five in the afternoon it reached Leicester, when it discharged itself in such sudden and copious torrents of rain, that the lower part of the town was soon flooded, and every available bucket, and even the fire-engines,

were put in requisition to clear out the water. The noise of the descending torrents for a time almost drowned the roar of the thunder. The air was at the same time rent and traversed by flashes and streaks of lightning, which soon became nearly incessant. "A great deal of the lightning," says one of the observers, "was forked, but more came in that form which is commonly, but erroneously, termed 'fire-balls.' Immense masses of flame descended to the earth, blinding every spectator for some seconds; and, as these masses exploded with terrific force, there were few persons who did not hold their breath, and think of those expressive words of Job, 'By the blast of God they perish, and by the breath of his nostrils they are consumed.' Business was entirely at a stand-still, and no one jested at his neighbour's timidity, or boasted of his own fearlessness."

The extraordinary duration of this storm was as remarkable as its violence; for from five o'clock until nine in the evening there was scarcely any sign of its abatement, and up to midnight flashes of lightning continually illumined the distant range of forest hills. It was at five minutes past eight, after one or two peals of unusual distinctness, that

the church of St. George was struck, with a report resembling the discharge of cannon, and with a concussion of the air which shook the neighbouring houses, and extinguished a lamp burning at the entrance of the News-room, many hundred feet distant. The sexton had gone into the church, as usual, to toll the eight-o'clock bell; but was so terrified by the "fire-balls" he saw in the sky, and by the fact, that once or twice the clapper struck the side of the bell without his agency, that he made his work as short as possible, and had just gone out and locked the churchyard gate, when the stroke fell. Two of the spectators of this awful event were Captain Jackson and the Rev. R. Burnaby, rector of the parish, who both described the flash as a vivid stream of light, followed by a red and globular mass of fire, and darting obliquely from the north-west, with immense velocity, against the upper part of the spire. For the distance of forty feet on the eastern side, and nearly seventy on the west, the massive stonework of the spire was instantly rent asunder and laid in ruins. Large blocks of stone were hurled in all directions, broken into small fragments, and in some cases, as there is every reason to believe,

reduced to powder. One fragment of considerable size was hurled against the window of a house three hundred feet distant, shattering to pieces the woodwork, as well as fourteen out of the sixteen panes of glass, and strewing the room within with fine dust and fragments of glass. It has been computed that a hundred tons of stone were on this occasion blown to a distance of thirty feet in three seconds. In addition to the shivering of the spire, the pinnacles at the angles of the tower were all more or less damaged, the flying buttresses cracked through and violently shaken, many of the open battlements at the base of the spire knocked away, the roof of the church completely riddled, the roofs of the side entrances destroyed, and the stone staircases of the gallery shattered. The top of the spire, when left without support beneath, fell perpendicularly downwards, inside the steeple, causing much devastation in its descent. Falling through the uppermost story, and carrying along with it the bell and its solid supports, the ruined spire entered the room containing the clock, dashed the works to pieces, and, penetrating the strong and well-supported floor, descended with additional momentum through the third and fourth



SECTION OF ST. GEORGE'S CHURCH, LEICESTER.
(The dotted lines show the course of the discharge.)

floors (the latter being that just deserted by the prudent sexton) and reached the paved vestibule with so furious a shock as to drive in a portion of the strong foundation-arch, by which the weight of the whole tower was supported. On looking upward from the scene of ruin in this vestibule the tower appeared like a well, so small were the vestiges of its various stories.

After minute examination, it was evident that the course of the lightning had been nearly as follows. The flash first struck the gilded vane, marks of lightning being perceptible between its bevelled edges. After traversing the vane and spindle, and the terminating iron supports, the only path left for the fluid was through a series of iron cramps, separated by masses of sandstone; and here it was that the explosion commenced—the stone being torn and hurled aside as it came in the path of the lightning to the lowest lead-lights of the spire. Most of these iron cramps were found to be powerfully magnetic; and one of them, eight weeks afterwards, sustained a very considerable brush of steel filings at its edges. The lattices of the lights on three sides of the spire were little injured; but on the fourth side, the stone-work

was shattered, and the lattice singularly twisted, and partially fused. Here it appears another violent explosion took place, and the lightning diverging struck the north-west pinnacle, attracted apparently by the copper bolt by which the stones were held together. It also struck the large cast-iron pipe on the other side the spire, reaching from the tower-battlements to the roof of the church; and during its passage down the pipe, and at an inequality in the surface of the metal, it displayed the most extraordinary expansive force, bursting open and scattering to a distance portions of metal of great solidity and weight. From the lead-work of the roof the lightning was conducted to the leaden gutters, and so finally to the earth.

The course of the remaining current in the interior of the tower was first to be traced on the lattices of the belfry, then in the clock-room, where the works of the clock were strongly magnetized, thence in at least three different directions to the outside of the tower. The external faces of the clock were not much altered, the hands were, however, slightly discoloured, and the blackened surfaces of the dials covered with streaks, as if smeared with a painter's brush. On

quitting the dial faces on the northern and southern sides of the tower, the lightning evidently fell upon the leads of the side lobbies, and was finally carried off by the two iron pipes connecting their roofs with the earth. Both these pipes were chipped and injured, and one of them was perforated, as if with a musket-shot, a few inches from the ground. The edges of this fracture were found to possess magnetic power. Thus, besides the division of the current at the upper part of the spire, there was a second division in at least three directions from the clock-room and dial faces. The roof of the church throughout its whole extent showed signs of an extraordinary diffusion of the electric current; and in almost every place where one piece of metal over-lapped another, a powerful explosion had evidently taken place. The appearance of the church after this disastrous accident is given in the engraving at page 178.

Should a fuller and more particular account of this visitation be required, our readers will find it in Mr. Hollings's "Lecture on Lightning Conductors," delivered at Leicester soon after the event, and now published at the request of his

audience. Appended to this lecture is a remarkable and very recent case of another church struck by lightning during Divine Service. On the 29th of August, 1847, while the congregation were engaged in singing the hymn before the sermon in the parish church of Welton, Lincolnshire, and the Rev. Mr. Williamson had just ascended the pulpit, the lightning was seen to enter the church from the belfry, and instantly an explosion occurred in the centre of the edifice. All that could move made for the door, and Mr. Williamson descended from the pulpit, endeavouring to allay the fears of the people. But attention was now called to the fact that several of the congregation were lying in different parts of the church, apparently dead, some of whom had their clothing on fire. Five women were found injured, and having their faces blackened and burnt; and a boy had his clothes almost entirely consumed. A respected old parishioner, Mr. J. Brownlow, aged sixty-eight, was discovered lying at the bottom of his pew, immediately beneath one of the chandeliers, quite dead. There were no marks on the body; but the buttons of his waistcoat were melted, the right leg of his trousers torn down, and his coat

literally burnt off. His wife in the same pew received no injury. Immediately beneath the body of Mr. Brownlow were found thirty or forty small holes in the floor of the pew. The church was for a long time filled with sulphurous smoke, as if it was on fire; but this fortunately was not the case.

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CHAPTER VI.

AMOUNT OF DAMAGE FROM LIGHTNING TO CHURCHES—GUNPOWDER-MAGAZINES—SHIPS—NECESSITY OF ADOPTING A PERFECT SYSTEM OF PROTECTION—EARLY ATTEMPTS AT PROTECTION—THE THRACIANS—THE ETRUSCANS — REFUGE IN CAVES—FISH NOT SECURE FROM LIGHTNING—PROTECTING PROPERTY OF BED-CLOTHES—OF SEAL'S SKINS — SNAKE'S SKINS — OF CLOTHES GENERALLY — EFFECT OF COLOUR IN HIDES OF ANIMALS — ACTION OF LIGHTNING ON VARIOUS TREES — DANGER OF SEEKING REFUGE UNDER TREES—PROTECTIVE POWERS OF GLASS—DANGER FROM METAL WORN ABOUT THE PERSON—DANGER TO ANIMALS PLACED IN A LINE—PRECAUTIONS TO BE OBSERVED DURING THUNDER-STORMS—EFFECT OF SLATE ROOFS —PRACTICE OF CLOSING WINDOWS DURING A THUNDER-STORM—PRACTICE OF THE ESTHONIANS AND OF THE JEWS —PERSONS STRUCK DO NOT SEE THE FLASH—ELEVATED PLACES NOT ALWAYS STRUCK IN PREFERENCE TO LOW ONES—TREES DO NOT ALWAYS PROTECT A HOUSE—OBJECTS STRUCK EXERT NO ATTRACTION ON LIGHTNING—USELESS CUSTOMS OF KINDLING LARGE FIRES, FIRING CANNON, AND RINGING LARGE BELLS DURING A THUNDER-STORM.

In examining the numerous accidents from lightning which have occurred during a long series of years, it appears that the number of persons killed has been comparatively small; while the damage to buildings, ships, trees, and various de-

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ST. GEORGE'S CHURCH, LEICESTER, DAMAGED BY LIGHTNING.

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In examining the numerous accidents from lightning which have occurred during a long series of years, it appears that the number of persons killed has been comparatively small; while the damage to buildings, ships, trees, and various de-

scriptions of property has, on the contrary, been enormous.

Fuller, in his Church History of Britain,* says that "there was scarce a great abbey in England, which (once at the least) was not burnt down with lightning from heaven. 1. The Monastery of Canterbury, burnt anno 1145, and afterward again burnt anno 1174. 2. The Abbey of Croyland, twice burnt. 3. The Abbey of Peterborow, twice set on fire. 4. The Abbey of S. Marye's in Yorke burnt. 5. The Abbey of Norwich burnt. 6. The Abbey of S. Edmondsbury burnt and destroyed. 7. The Abbey of Worcester burnt. 8. The Abbey of Gloucester. 9. The Abbey of Chichester burnt. 10. The Abbey of Glastonbury burnt. 11. The Abbey of S. Mary in Southwarke burnt. 12. The church of the Abbey of Beverley burnt. 13. The steeple of the Abbey of Evesham burnt."

On examination, the records of our own time will probably excite surprise at the enormous amount of damage which our churches have sustained from lightning within a very few years.

* Fo. 1655, page 300.

The following list, by no means a perfect one, will serve to convey some idea of this damage.

1822.	August...	Church at Chatham............	Spire ripped open.
	15 Sept....	Rouen Cathedral	Struck at 5 o'clock, a.m. set on fire.
1823.	Feb. 4	Shaugh Church, near Plymouth, on the borders of Dartmouth	Tower struck and much shattered. An iron conductor had been erected about two years before, but this had rusted and gone to decay.
1824.	Nov.	Charles Church, Plymouth	Steeple struck, and the small brass rod erected as a lightning conductor knocked to pieces.
About 1825........		Torrington Church, North Devon	Tower and steeple ruined: they had to be rebuilt.
1828.	Sunday, June 22	Kingsbridge Church, Devon	Steeple rent, and other damage.
About 1829........		Alphington Church, near Exeter	Tower rent.
1830.	Aug. 26...	Marlborough Church, near Kingsbridge, Devon......	Tower and church severely damaged.
1836.	Jan. 29 ...	Black Rock, near Cork	Spire demolished.
	Nov.	Christ Church, Doncaster...	The spire was shattered, and the church greatly injured —the roof was smashed in, and the churchyard presented a scene of ruin and devastation. The spire was surmounted by a ball of glass to keep off the lightning.
1841.	Jan.	Spitalfields, London	Spire rent, and other damage.
	———	Streatham	Spire nearly destroyed and church set on fire.
	Aug. 24 ...	St. Michael's, Liverpool.....	Beautiful spire shattered, and clock injured.

1841.	Aug. 24...	St. Martin's, Liverpool	Spire shattered, and other damage.
1842.	April 24...	Brixton Church, near London	Dome and building much rent.
	July 28 ...	St. Martin's, London	Spire shattered. Cost of repair, £1,500.
843.	April 25...	Exton Church, Rutlandshire	Spire destroyed; church set on fire, and nearly destroyed.
	May 25 ...	St. Mark's, Hull	Slightly damaged.
	Oct.........	North Huish, near Modbury, Devon	Steeple shattered.
1844.	March.....	Oving Church, near Chichester	Spire damaged.
	Spring ...	St. Clement's, London	Clock injured.
	July	Magdalen Tower, Oxford...	One of the pinnacles damaged —staircase injured.
	—— 20 ...	Stannington Church, nr. Sheffield.....................	Seriously damaged.

A writer in Nicholson's "Journal of Science" states that he has made a calculation of the average annual amount of damage done by lightning in England alone, and that it cannot be far short of 50,000*l.*

Some of the most disastrous accidents from lightning have proceeded from the explosions of magazines of gunpowder. On the 18th of August, 1769, the tower of St. Nazaire at Brescia was struck by lightning. Below this tower were vaults containing 207,600 pounds of gunpowder belonging to the republic of Venice. This enormous quan-

tity of gunpowder exploded, destroying a sixth part of the beautiful city of Brescia, and greatly injuring the remaining parts. Three thousand persons perished. The tower of St. Nazaire was thrown up whole into the air, and fell in a shower of stones. Portions of the ruins were found at enormous distances. A similar accident occurred to a magazine at Malaga, on the 18th of August, 1780; and at Tangiers, on the 4th of May, 1785. At Luxembourg, on the 26th of June, 1807, a magazine of gunpowder, built in former times by the Spaniards on a solid rock, was struck by lightning, and blown up; more than 28,000 pounds, or about twelve tons of gunpowder, were fired, by which the lower part of the town was laid in ruins. During the night of the 28th November, 1829, lightning fell upon the citadel of Navarino, and setting fire to the powder-magazine, blew it up, destroying the whole building. One hundred French artillery-men lost their lives by the accident. On the 22d April, 1843, lightning fell upon the castle of Pozzalon, in the province of Noto, and descending into the magazine, blew it up. On the the 23d April, 1843, a similar accident occurred to a powder-magazine at Guncon, in Spain.

Let us now glance at the damage done to shipping by this destructive element.

"In the British Navy the effects of lightning have been most disastrous. Since the commencement of the war in 1793, more than two hundred and fifty ships are known to have suffered in thunder-storms. It is not possible to state with any degree of precision the total amount of damage done, as all the instances in which ships have suffered cannot be well ascertained; some idea, however, may be formed of it, from the following facts, derived from the official journals of Her Majesty's ships, deposited at the Admiralty. In one hundred and fifty cases, the majority of which occurred between the years 1799 and 1815, nearly one hundred lower masts of line-of-battle ships and frigates, with a corresponding number of top-masts and smaller spars, together with various stores, were wholly or partially destroyed. One ship in eight was set on fire in some part of the rigging or sails; upwards of seventy seamen were killed, and one hundred and thirty-three wounded, exclusive of nineteen cases in which the number of wounded is returned as 'many' or 'several.' In one-tenth of these cases the ships were com-

pletely disabled, and they were compelled in many instances to leave their stations, and that, too, at a critical period of our history. The expenditure, inthese few cases, in the mere material, could not have been far short of 100,000*l.* sterling. So that if the whole amount of the loss to the public, in men, in money, and in services of ships, could be ascertained, it would necessarily prove to be enormous; more especially when we take into account the expense of the detention and refit of the damaged vessels, the average cost of a single line-of-battle ship to the country being 100*l.* per diem, and upwards. Now between the years 1809 and 1815, that is to say, within the short period of six years, full thirty sail of the line, and fifteen frigates, were more or less disabled."

Even in time of peace, when the Navy has been greatly reduced, many fatal accidents to our ships have occurred. On the Mediterranean station alone, between the years 1838 and 1840, eight ships were struck by lightning, several of them severely damaged, and one of them set on fire. In other parts of the world, similar accidents have been numerous, and it is also highly probable that many a ship which has been reported as

"missing," has been destroyed in thunder-storms, without any of the crew having been spared to record its fate.

The East India Company's ships have been subject to numerous disasters, especially within the tropics, where thunder-storms are of more frequent occurrence, and, if possible, more terrible in their action than within the temperate zones. Our mercantile marine, engaged in active commerce in every quarter of the world, is peculiarly exposed to danger from lightning. Indeed, it is scarcely possible to estimate the amount of damage from lightning to this class of ships; but such a case as the following will show how sudden and complete may be the destruction of a ship, with an inflammable cargo on board. In May 1820, a fine vessel, the *Tanjore*, commanded by Captain Dacre, sailed from London with goods and passengers for Ceylon and Calcutta. The voyage was rapid and favourable in every respect, and the vessel seemed perfect in all its arrangements, with only one exception: there were no lightning conductors. Judge Ottley and several missionaries were passengers in this vessel; and on their arrival at Ceylon, they were landed on that island, and

the ship stood off at about forty miles distant from the shore. At eight in the evening, after they had left the ship, the horizon became suddenly dark and lowering, and a severe squall of wind ushered in a most terrific storm. Two men were on the top-gallant forecastle, when an awful flash darted upon them, and destroyed them in an instant—literally tearing open their bodies. Many other persons were struck down and rendered insensible, and all on board were severely electrified. Part of the cargo consisted of brandy, and this igniting, burnt up with such fury that every part of the vessel was quickly in flames. There was not even time to clear and hoist out the long-boat: the yawl and a small quarter boat were all the means of escape, and the crew and remaining passengers (forty-eight in all) hurried into these with the greatest precipitancy. They could not procure the smallest article of food nor a drop of water; a binnacle compass, a box of the ship's papers, and a box of dollars, were all they saved. They had only three oars for the two boats, and it was with the utmost difficulty they kept clear of the burning ship, whose appearance was awfully grand. She went down at four o'clock the next morning, and at

ten the boats' crews met with a native vessel, which took them to Trincomalee.

But the fire thus communicated to a ship by lightning does not always act with such terrible speed; it may lie hid for hours, and even days, and then burst forth with irresistible fury. Lightning has been known to produce a *secret burning* in the heart of masses of timber and other bodies, as, for example, the *Dictator*, a sixty-four gun-ship, was struck at Martinique, in 1794, and damaged. Two days after, smoke was seen issuing from the figure-head; when this was cut down a nest of fire was discovered within it. In 1799, the *Principe Real*, a Portuguese seventy-four, was struck off Malta, and went into harbour. After lying at anchor some hours, the whole of the mast burst into a flame.

That a ship may be sunk in consequence of the damage produced by lightning is evident from such cases as the following. H. M. frigate, *Squirrel*, while off Cape Coast on the 23d February, 1805, was struck by lightning. The mainmast was damaged and rendered useless; the top-mast and top-gallant-mast were shivered; a plank in the side stove in; all the caulking loosened from the

fore to the main chains, so that the ship made eight inches of water in an hour. The barque *John and James*, while off Malta, 2d of February, 1839, was struck by lightning; the masts were knocked to pieces, and great damage done below. The discharge passed out through the ship's side, just below the water-line, starting seven planks, three above and four below the water, so that the sea rushed into the ship with rapidity. Ballast and weights were placed on the opposite side, so as to raise the leak out of the water; and in this way she was with difficulty got to Malta without sinking. The French corvette, *Coquin*, while at anchor in the Bay of Naples, on Christmas-day, 1820, was struck by lightning, which passed completely through the bottom, below the water's edge. The boats of an English squadron assisted in running the ship on shore in the mole to prevent her from sinking. If these accidents had happened out at sea, and by night in a gale of wind, the ships might now be on the "missing" list, and no one probably would have known their fate.

In considering, therefore, the amount of damage from lightning, whether in our possessions at home, our colonies abroad, our Navy and our merchant

ships, it is not too much to state that the British nation is liable to damage from most of the thunder-storms that visit the earth's surface. It certainly does, then, appear to be a matter of first-rate importance to adopt such a system of lightning conductors as the experience of years has found to be efficacious,—such a system of protection to our buildings and our ships as may meet all possible conditions of the electrical discharge; and as the subject is one in which everybody is interested, either as regards the protection of his person or his property, or the property of the nation, it is natural to suppose that authentic information connected with the subject will be read with interest.

The necessity of adopting some means of protection against lightning was felt at a very early period; but while electrical science was either unknown, or very imperfectly understood, the means of protection were of little or no avail. The Thracians, according to Herodotus, were in the habit of shooting their arrows in the direction of a thunder-cloud. These arrows, being pointed metallic bodies, might have deprived the cloud of a small portion of its electric matter. The Etruscans, according to Pliny, had a secret method by

which they could draw lightning from the clouds and guide it at their pleasure. Numa is said to have known the method; and Tullus Hostilius, committing some oversight in the performance of the ceremony, was himself struck. "For Numa substitute Franklin, and for Tullus, Richmann, and the Roman legend is converted into a true historical record of the last century."*

The ancients believed that lightning never struck deeper into the earth than five feet. Hence, caverns were favourite places of resort during thunder-storms. According to Suetonius, Augustus always sought refuge in some cave or vaulted place during a storm. We have already seen, in the formation of vitreous tubes, that lightning descends to a much greater depth; but it is certain that at far greater depths than these tubes have been traced to, a person is not always secure, because lightning has been known to descend a deep mine. For example, on the 19th October, 1843, three men were struck by lightning at the bottom of the shaft of Purkenowerth mine, at the depth of 660 feet below the surface. The

* Cabinet Cyclopædia. Electricity: Vol. ii.

lightning is supposed to have passed down a chain in the shaft.

According to Kæmpfer, the emperors of Japan sought refuge during storms in a grotto containing a reservoir of water; the water being intended to extinguish the fire of lightning. It certainly might act as a conductor, but not as a safeguard, for fish have been destroyed by lightning throughout a wide extent of their liquid habitation. It is stated by Valvasor, in the "Philosophical Transactions," that lightning in the year 1670 having fallen on the lake of Zirknitz, such a quantity of fish almost immediately floated upon the surface that the neighbouring inhabitants collected twenty-eight waggon-loads for manure. Again, on the 24th September, 1772, lightning descended at Besançon, and immediately the surface of the water was covered with stunned fish, which were floated along by the stream.

It was long a favourite opinion that persons in bed had nothing to fear from lightning. Facts are generally, but not universally, in favour of this conclusion. On the 3d July, 1828, a cottage at Birdham, near Chichester, was struck by lightning. It destroyed with a crash the

wooden part of a bed, threw the bed-clothes on the ground, together with the mattrass and the person sleeping on it, without doing him any injury. Again, on the 9th of the same month, at Great Houghton, near Doncaster, lightning removed the coverlid of a bed, and did no injury to its occupant. In the sixty-third volume of the "Philosophical Transactions," the Rev. Samuel Kirkshaw states that on the 29th September, 1772, at Harrowgate, a flash of lightning killed Mr. Thomas Hearthley while asleep in his bed, without even waking his wife, who was by his side. She complained of pain in her right arm, which, however, only lasted a few hours.

The Romans believed that seal's skin was a preservative against lightning; tents made of this material were constructed for timid persons during a storm. Augustus always wore one of these skins. In the Avennes, the shepherds at the present day wear in their hats the skins of snakes, which they believe to be a preservative against lightning. However fanciful these notions may be, yet some electricians have thought it probable that the kind of material in which a person is clothed may influence the course of the electrical

discharge. M. Arago mentions a case in which a church was struck with lightning during the celebration of mass; of the three officiating priests, two were struck dead, and the third, who alone wore *silk* vestments, escaped unhurt. Cases of this kind, however, do not warrant any confidence in the protecting power of silk and other non-conducting articles of dress; for the conducting power of the human body is not diminished by the nature of the dress which covers it.

Colour seems, also, to have some influence on the course of the discharge. M. Arago cites three cases, in which horses and oxen having white spots were struck by lightning, and had all the white hair burnt off, while the remainder of the hide was uninjured. It has been supposed that certain trees are never struck by lightning. Suetonius relates, that when a thunder-storm threatened, Tiberius never failed to wear a crown of laurel leaves, under the idea that lightning never touched the leaves of this tree.* The

* We find this superstition repeated in Alberti's work on architecture (*De Re Ædificatoriâ*, Florence 1485; translated by Leoni, London 1726): "There are some things in nature which are endued with properties by no means to be neglected; par-

opinion that certain trees are never struck by lightning is still common. In 1787, Mr. Hugh Maxwell stated to the American Academy, that according to the information he had collected, he thought himself warranted in affirming that lightning often struck the elm, the chestnut, the oak and pine, and sometimes the ash; but that it never fell upon the beech, the birch, or the maple. Captain Dibden states that in the forests of Virginia, the pines, though considerably higher than the oaks, were not so frequently struck; and he adds, "I do not remember in those localities where the oak and the pine grew together to have seen the latter scathed by lightning." Other observers, however, have witnessed the destruction by lightning of all these supposed favoured trees. The laurel has been destroyed by that meteor, and M. Héricart states that an aged beech in the middle of the forest of Villers-Cotterets, was struck with lightning, and nearly demolished in July 1835. From the non-conducting property

ticularly that the laurel-tree, the eagle, and the sea-calf, are never touched by lightning. There are some, therefore, who suppose that if these are inclosed in the wall the lightning will never hurt it."—Lib. iii.

of resinous bodies, it might be supposed that the pine and other resinous trees would be safe from lightning. Mr. Maxwell, however, places the pine among trees which are most frequently struck. In the case of the *Fisgard* frigate, struck by lightning (represented in the frontispiece, and described at page 244), the pine-trees on shore were set on fire by the electric fluid.

During a thunder-storm, persons have been advised to keep in a free and open country, and to avoid trees. Dr. Winthorpe advises persons surprised by a storm in the country, to keep at the distance of from sixteen to forty feet from some tall tree. A station still more favourable would be found in a spot at the distance just named from two or more neighbouring trees. Henley advises, when there is only a single tree, to stand from sixteen to twenty feet beyond a perpendicular line let fall from the extremity of its longest branches.

Glass being a non-conductor, it was supposed that lightning never touched that substance; hence it was at one time customary to place thick balls of glass on the projecting points of buildings, ships, and lighthouses. The vane-rod of Christ

Church, at Doncaster, was thus furnished with a glass ball; but, in November 1836, the spire of this church was struck by lightning, and so greatly damaged that the repairs cost about 1,000*l*. sterling. It has also been supposed that a chamber constructed wholly of glass would be a perfectly secure refuge. Hence chambers or cases of glass have actually been made for the use of those persons who are apt to be overcome with terror during a thunder-storm. The following cases show how useless is this precaution:—The great thunder-storm which injured the palace of Minuzzi, in the territory of Ceneda, in Lombardy, on the 15th June, 1776, pierced or broke more than 800 panes of glass. Again, in September 1780, when Mr. James Adair was prostrated by a violent stroke of lightning, which killed two of his servants, in his house at Eastbourne, he was standing behind a glass window. The window-frame was not at all injured, but the lightning reduced all the glass to powder.

It may be supposed that the rupture of the glass on such occasions is caused by the violent concussion of the air. Such, however, is not the case. Some years ago a gentleman at Poole was

writing at a desk before a window, when a flash of lightning passed before him, accompanied, at the same moment, by a loud clap of thunder; the lightning cut out from one of the panes a perfectly circular disc of glass, which fell upon the paper on which the observer was writing. No other damage was done, and the glass pane was not even cracked.* Other cases of the same kind are on record. On the 17th September, 1772, the lightning, which fell on a house at Padua, pierced a pane in a window on the ground floor with a clean round hole, such as a gimlet would make in wood. Again, Caseli observed upon the glass of his windows, immediately after a flash of lightning, in 1778, a number of small round holes, with scarcely any cracks or breaks near them. In September, 1824, a thunder-bolt having fallen on the house of Mr. Brenmer, at Milton Comage, one of the panes of the window was found pierced by a circular hole of the size of a musket-ball; in the other parts of the pane there was not a single crack or fissure. A perfectly circular hole of this sort, without fissures, cannot be the consequence of

* Communicated to the writer by Thomas Bell, Esq., F.R.S.

noise and detonation, but is rather a proof of the extreme velocity of lightning; at any rate, these facts will undeceive those persons who imagine glass panes to be a complete safeguard against lightning.

When lightning strikes individuals, it more particularly attacks any metal they may have about their persons; so that it may reasonably be concluded that any metal worn about the person increases the danger of being struck. For example, on the 21st July, 1819, lightning fell upon the prison of Biberach, in Suabia, and there struck, in the common apartment, in the midst of twenty prisoners, *one* condemned captain of brigands, who was chained round the waist. Even those trifling metallic articles which form part of our ordinary dress are often affected by lightning in a singular manner. Saussure and his companions being in the Breven in the year 1767, during a thunder-storm, whenever any of the party raised his arm and extended his finger, he felt a pricking sensation at its point. One of the party who had a gold band round his cap, heard also an alarming buzzing noise round his head. "We drew sparks of light from the golden button of the

band, as also from a metallic ring which surrounded a large stick we carried with us." "Confer the most trifling additional intensity on the storm," remarks Arago, "and the small gold band and its metallic button, under such circumstances, will become causes of explosion, and the wearer would have been injured by lightning rather than his companions, whose hats were free from golden bands and metallic buttons." The following fact, mentioned by Constantini in the year 1749, may be taken as an illustration:—During a thunder-storm a lady raised her arm to shut a window,—the lightning flashed, and her golden bracelet so completely disappeared that no vestige of it could subsequently be found: otherwise the lady only received the slightest possible injuries. A somewhat similar case is reported in Professor Jameson's "Edinburgh New Philosophical Journal" for 1844. During a violent thunder-storm, a fishing-boat belonging to Midyell, in the Shetland Islands, was struck by lightning. The electric fluid came down the mast, which it tore into shivers, and melted a watch in the pocket of a man who was sitting close to the side of the mast, without injuring him. Not only was the man altogether

unhurt, but his clothes also were uninjured; and he was not aware of what had taken place until, on taking out his watch, he found it was fused into one mass. The traveller Brydone relates a circumstance which happened to a lady of his acquaintance who was regarding a thunder-storm from her window. It lightened, and her bonnet, and her bonnet only, was reduced to ashes. According to Brydone, the lightning had been attracted by the metallic wire which maintained the shape of her bonnet and supported its softer materials. Hence he proposes that these wires should be abandoned, and protests against the prevailing fashion of maintaining the tresses and ornamenting the hair with gold and silver pins. And in the very natural apprehension that this caution would be disregarded, he offers this somewhat ridiculous advice: —"That every lady should wear a small chain or thread of brass wire, which she should hang, during the time of a thunder-storm, to the wires of her bonnet, by which the fulminating matter might pass to the earth, instead of traversing the head and other members."

It will naturally be concluded, from these examples, that it is better, during a thunder-storm,

to have no metal about the person. But, it may be asked, is it of the slightest consequence to regard the increase of danger which a watch, or buckles, or the money in your purse, or which the wires and chains and pins used in a lady's toilette produce? To this question, says Arago, no general answer can be given, for every one will regard it through his own prepossessions, and will, more or less, be determined by the apprehensions with which a thunder-storm inspires him.

It appears from various observations, that when lightning falls upon man or animals placed near each other, whether in a straight line, or an unindosed curve, it is generally at the two extremities of the line that its effects are most intense and hurtful. On the 2d August, 1785, the lightning descended upon a stable at Rambouillet, where there were thirty-two horses ranged in a line, side by side; thirty were overturned by the stroke; only one, however, was instantly struck dead, and this one occupied one of the extremities of the line; another, which was very severely wounded, and subsequently died, was at the other extremity. Again, on the 22d August, 1808, lightning struck a house in the village of Knonau, in Switzerland.

Five children were sitting upon a bench in a room on the ground floor; of these, the first and last were killed on the spot, whilst the others experienced only a violent shock. In the year 1801 lightning fell on a windmill at Praville, near Chartres, set it on fire, and consumed it. At the moment the miller was walking between a horse and a mule which were both laden with corn; the two animals, struck at the same instant, were killed on the spot; the miller escaped with being fearfully stunned, with having some ringlets of his hair burnt, and with the loss of his hat.*

In explaining the above facts Arago instances the case of a bar of metal struck by lightning, which is apparently not much damaged except at the spots where it made its entrance and its exit.

* It appears from the last fact, and from several others quoted by Arago, that men more powerfully resist the effects of lightning than horses and dogs. On the 12th April, 1781, near Castres, three gentlemen on horseback were struck by lightning; the horses were killed, but only one of the riders became its victim. In June, 1826, a flash of lightning killed a mare near Worcester, whilst the boy who was leading it experienced no serious injury. In June, 1810, when M. Cowen's dog was sitting by his side, lightning entered the apartment and killed the dog on the spot, whilst M. Cowen himself was scarcely conscious of any shock.

It may readily be supposed that it is the same also with bodies of a different nature; but how this rule can extend to instances in which there are considerable interruptions of continuity, does not so readily appear. How it happens that thirty horses, placed as horses usually are in a stable, should be considered, as far as the effects of lightning are concerned, as a single continued mass, having a beginning and an end, will probably surpass the comprehension of every one. It is difficult, however, to offer any other explanation of the curious phenomena just noticed.

Franklin has given directions for the use of those persons who, being alarmed at lightning, are in houses unprotected by lightning conductors at the time of a thunder-storm. He advises them to avoid the neighbourhood of chimneys, because lightning often enters into rooms by them, soot being a conductor of electricity. For the same reason a person should move as far as possible from metals and from mirrors and gilded articles. The best place seems to be in the middle of the apartment, provided there is no lamp hanging from the ceiling. A person is less exposed by avoiding contact with the walls and the floor, and

hence the safest of all expedients is to retire into a hammock suspended by silken cords in the centre of a large room. When this cannot be done, it is advisable to place between oneself and the floor some badly conducting substance. Accordingly, a chair may be placed on glass, or pitch, or on mattresses. These precautions certainly diminish the danger, but they do not wholly remove it. In fact, there are examples of glass, pitch, and several thick mattresses having been traversed by lightning. Besides, it must not be forgotten, that if the lightning does not encounter in a chamber a bell-wire, which will lead it out, it may dart from one point to an opposite point, and strike individuals in the centre, even though suspended in hammocks. All the precautions which have been given may be summed up in a very few words. The position of safety is that in which the body cannot assist as a conductor to the passage of the lightning. The position of surrounding bodies must therefore be attended to, and a person must occupy such a place, whether insulated or not, that the lightning will not make use of him as a stepping-stone in its descent to the earth.

According to Nollet, the roofs of those belfries

which are covered with slate are more frequently injured by lightning than similar roofs covered with stone. The cause of this seems to depend upon the facility with which, during rain, the wood-work, and more especially the planks on which the slates rest, become moist, and upon the greater number of iron nails required to fasten them.

It is common for people to close their windows during a thunder-storm, in order to keep out the wind and the rain. In some countries, however, the practice is supported on superstitious grounds. In the Russian province of Esthonia, for example, it is the fear of leaving an entrance for the evil spirit whom God is pursuing during a thunder-storm, which leads to the close shutting up of a house, even to the smallest crevice. In some countries the Jews act in a manner directly the reverse of the Esthonians. As soon as lightning flashes from the sky they open their doors and windows, that their expected Messiah, whose advent they anticipate with thunder, may have free entrance.

Lightning moves with such extraordinary velocity, that it is not uncommon for persons to be

struck before the flash has made any impression on the eye. On this account, says Arago, "it appears to me that timid individuals may be spared many moments of anguish during thunder-storms, were it proved that nothing is to be apprehended when the flash has been seen;" because what is seen is nothing more than a luminous impression on the eye, produced by lightning, which, even before the mind is capable of recognising it, is already hundreds or even thousands of miles off.

There are many recorded facts which seem to prove that lightning strikes before it becomes visible. For instance, on the 20th December, 1752, Mr. Thomas Olivey, a farmer in Cornwall, who was struck down unconscious by a fearful thunderbolt, neither heard the noise nor perceived the light of the meteor, so that on coming to himself at the end of a quarter of an hour, his first inquiry was, "Who struck me?" On the 18th of February, 1770, the Rev. Anthony Williams was struck by a thunderbolt, which greatly damaged the parish church. On recovering, after having been long in a fainting state, he declared that he had neither seen the lightning nor heard the thunder. A gardener, who was struck down

by lightning near Manchester, told Mr. Luke Howard that at the moment of the accident he neither saw the lightning nor heard the thunder. On the 17th June, 1829, two persons employed in repairing the spire of Salisbury cathedral were struck down senseless by a vivid flash of lightning, accompanied by a very loud clap of thunder. The men had been engaged in forming a scaffold round the spire at the weather-door (a height of 380 feet from the ground), and had fortunately just retired within the door to avoid an expected storm, otherwise the effects of the shock must have proved fatal. One of the men (H. N. Reeves, whitesmith) was so affected by the shock as to be rendered totally insensible for a considerable time, at the expiration of which he had no recollection of even hearing the thunder; the other (an older man, named Samuel Applin) recovered very soon, and found his right arm much affected by a numbness, which did not go off for some time.

There is no doubt that lightning generally strikes elevated places rather than lower objects, and hence it has been said that a house surrounded by steeples has nothing to fear. There are, however, many circumstances which may compensate, or more

than compensate, for the influence of superior height; and there are facts which prove that the lightning selects, as it were, a low edifice in the midst of tall buildings. For example, on the 15th March, 1773, the lightning fell at Naples upon a house occupied by Lord Tilney, although this house was surrounded on all sides, at the distance of four or five hundred paces, by the towers and domes of a great number of churches. It may be added that these domes and towers were all wet with a heavy rain. It is also well known that labourers have been struck with lightning close to hayricks and corn-stacks, which remained uninjured though twice or three times higher than the sufferers.

It has also been supposed that trees which overtop a house at small distances protect it from lightning. There is no doubt that trees have considerable influence on a thunder-cloud; and when a storm passes over a forest, it is decidedly enfeebled by the quantity of electricity carried off or dispersed by the trees. Trees, however, do no more than diminish the power of the thunderbolt; they have no protecting virtue, as the following facts prove. On the 2d September, 1816, lightning

fell at Conway, Massachusetts, on the house of Mr. John Williams, and did much mischief, although in the immediate neighbourhood were a number of Italian poplars, of from sixty to seventy feet in height, whose summits overtopped the house by between thirty and forty feet. One of the poplars was only six feet from the spot where the lightning entered the house. None of the trees were struck. On the 17th August, 1789, a storm did much damage to the house of Mr. Thomas Leiper, at his mills, near Chester, United States. The house stood at the foot of a tolerably steep ascent, within a few yards of a mill-dam. It was a stone building, two stories high at one end and three at the other. At each end were two stacks of chimneys rising from the roof, each furnished with pointed metallic conductors, which terminated in the ground a short distance only on account of the rocky soil. The lightning struck the western conductor, melting a considerable portion thereof; part of the discharge then bounded off from the conductor (tearing off a portion of the roof in its progress) to a copper water-gutter, running under the eaves, and connected with a copper spout, fixed to the wall, and discharging

the rain-water into a cedar tub, bound with iron hoops, standing on the ground. The lightning appears to have passed quietly along the copper the whole length of the gutter and spout. A few inches below the end of the spout it tore off and shivered to pieces an inch board, placed for the purpose of guiding the water into the tub; it then passed into the tub, and forced its way through it to the earth, splintering the tub in many

places. Another part of the lightning seems to have bounded off in like manner to the copper

spout on the opposite side, from which it was distant six or seven feet; it ran along the cornice, part of which it threw off, and coming round the opposite side, united with the first part of the discharge. It was evident, also, that a third portion was discharged into the earth by the conductor, for the surface of the earth was thrown up at its termination in the ground. Towards the west the surface, at the short distance of sixty yards, is at the level of the highest parts of the house. On this ground was an alley of large oaks. The storm came from the west; and before attaining a perpendicular position over the house, it must have passed the trees, which were much higher than the roof and chimneys; the trees, however, were spared, and the house was struck.

In considering cases of this kind, we must carefully bear in mind the fact, that buildings, ships, and other elevated points in the earth's surface, exert no attractive power on the thunder-cloud. The elevated point must be taken in connexion with the great plane in which it is situated. The attractive forces (as already shown in Chapter III.) are exerted between the plane of the sea or earth and the cloud above it; and not between the

spire of a church or the masts of a ship and the cloud; hence the primary cause of the discharge is not in the metals of the building or ship, as many persons suppose, but is out of them altogether, the exact point or line in which the air breaks down being determined by a variety of causes. The elevated points of a building or ship may form a channel for the passage of the shock, but it is not the only one, and is certainly not the cause of the discharge, which would take place sooner or later, whether the ship or building were absent altogether. This is proved by many recorded cases of lightning falling close to a ship without touching the masts at all, and also by badly conducting matter being struck in the immediate neighbourhood of metallic conductors. For example, during the thunder-storm which spread over the neighbourhood of Plymouth on the 25th of May, 1841, one of the large granite chimneys at the Royal Victualling Yard, about 120 feet high, was rent by lightning as far as the copper roofing of the bakehouse in connexion with it; here all damage ceased, the copper having free communication with the earth by the metal pipes fixed for carrying off the rain. At the same

time the lightning fell also on the top-mast of the sheer-hulk off the dockyard, about a mile and a-half distant.

Now it is important to observe that this chimney, which had no metal in its construction, and no projecting point, stood within a hundred yards of a clock tower in the same yard, which was furnished with a metal vane with cross pieces of metal; its dome was covered with copper, and it was furnished with a large metal conductor passing to the ground. In the sheer-hulk a very small metallic wire was led along the pole top-mast, and was connected with the large metallic chains attached to the mast and sheers. The height of this pole was comparatively low, and it was completely over-topped by the neighbouring spars of the *Cornwallis*, a line-of-battle ship, fully rigged and fitted with conductors on each of her masts. Now, when the disruptive discharges took place, one fell on the granite chimney, which had no metal in its construction, avoiding the clock tower, which had abundance of metal about it; and the other discharge fell on a pole containing only a thin wire of metal, and not on the capacious metallic conductors of the ship near it.

Attempts have been made at various times to dissipate thunder-storms by kindling large fires in the open air, by firing cannon, and by ringing large bells. These efforts seem to be in no way effectual; on the contrary, the ringing of bells has led to many serious accidents to the ringers, which might not otherwise have occurred. The danger to the ringers is similar to that which persons are exposed to who take refuge under a tree during a thunder-storm. Lightning strikes elevated objects, and especially the spires of steeples. The hempen cord attached to the bell, and commonly imbued with moisture, conducts the discharge to the very hands of the ringers; and hence so many deplorable accidents.

A German scientific writer found, in 1783, that in the space of thirty-three years lightning had struck three hundred and eighty-six bell towers, and had killed one hundred and twenty-one ringers, besides wounding a much larger number.

H. M. CORVETTE DIDO, PROTECTED FROM A PERILOUS STROKE OF LIGHTNING OFF JAVA, IN MAY, 1847. *See p.* 228

(*From a Drawing by N. M. Condy, Esq.*)

CHAPTER VII.

GENERAL CONDITIONS OF A THUNDER-STORM RECAPITULATED—NATURE OF THE DISCHARGE, CONSIDERED WITH A VIEW TO THE MEANS OF PROTECTION — THE FIRST LIGHTNING CONDUCTORS — VARIOUS CONDUCTING POWERS OF METALS — ADVANTAGES OF COPPER RODS —CONDITIONS TO BE OBSERVED IN THE APPLICATION OF LIGHTNING CONDUCTORS TO BUILDINGS—ACTION OF METAL ROOFS—EXTENT OF PROTECTION AFFORDED BY METALLIC CONDUCTORS—DIVISION OF THE DISCHARGE—CASE OF BI-FURCATION—CASE OF TRI-FURCATION —EARLY LIGHTNING CONDUCTORS FOR SHIPS — WIRE ROPES — THEIR INEFFICIENCY—SIR W. SNOW HARRIS'S CONDUCTORS—THEIR PERFECT SUCCESS—ILLUSTRATIVE CASES.

THE general conditions of a thunder-storm have been already stated to consist in the charging and discharging of a stratum of air, situated between two masses of clouds, in opposite electrical states, or between a mass of clouds and the earth beneath, also in opposite electrical states. The air obtains its charge of electricity in consequence of certain physical changes in the condition of the atmosphere, either with respect to heat, evaporation, currents of air, or other agencies not well understood. The discharge, however various may be

the effects resulting from it, is in all cases governed by well-known laws, such as those elementary principles deduced from the simple experiments given in the second chapter; namely, that bodies in opposite states of electricity attract each other; that electricity travels with ease along good conductors, and with explosive violence along bad ones.

The following beautiful and profound observations throw considerable light on the nature of the electrical discharge:—

"If we attentively examine the many recorded instances in which buildings and ships have been damaged by lightning, the course of the discharge may generally be traced; and this course is invariably determined through a given line or lines, which upon the whole oppose the least resistance to the neutralization of the electrical forces. Both space and time are, as it were, economized in the restoration of the electrical equilibrium; for however small we assume the duration of the discharge to be, or however limited the distance through which it strikes, both these quantities would become still less, were other lines of transit provided of still less resistance. This is the leading

phenomenon of all disruptive discharges; hence lightning seizes upon such bodies as lie convenient and ready for its purpose, absolutely avoiding other bodies, however near, from which it can receive no assistance. And it may be further observed, as a most wonderful and interesting fact, that at the instant before the explosion takes place, the stream of electricity, in the act of moving to restore the equilibrium of distribution, feels its way, as it were, in advance, and absolutely marks out the course it is about to take; an inductive action being impressed upon such bodies as happen to lie in the line or lines of least resistance; this previous induction, by a sort of foresight, determines the course of the discharge. Its progress, therefore, is not, as many imagine, left to the chances of the instant, to be, as it were, attracted or drawn aside by metallic bodies at any given point; on the contrary, the whole course of a stroke of lightning is already fixed and settled, before the discharge takes place."*

Bearing in mind the nature of a stroke of lightning, as illustrated by experiment and the large number of cases already cited, it will be evident

* Harris.

"that any artificial elevation on the earth's surface is, in respect of a thunder-storm, a mere point in one of the terminating planes of a great electrical disturbance. The electrical forces cannot therefore be supposed to operate exclusively between such an elevation and a charged cloud. A building or ship is struck by lightning only in consequence of its being a point in one of the electrified surfaces;" a mass of matter accidentally placed in a position favourable for the union of the two opposite electricities in a given direction. In all cases the electrical discharge falls upon those bodies which tend to assist its progress; if any damage is done it is in places where the line of good conductors is broken. In order, therefore, to protect buildings and ships from damage by lightning, it is necessary to provide a continuous line of conduction for transmitting the electricity to the earth,—an idea first suggested by Franklin, immediately after the identity between lightning and common electricity was established.

The first lightning conductor in England was erected in 1762, by Dr. Watson, at Payneshill. In Roman Catholic countries there was considerable difficulty in introducing lightning-rods,

on account of the superstitions of the populace. About the year 1776, Morveau caused metallic conductors to be erected on the house of the Academy of Sciences at Dijon. He was violently attacked for his presumption, and a mob assembled to pull down the heretical conductors, as they were called, and much mischief would probably have been done but for the assurance of the secretary that the gilded points of the conductors had been purposely sent from Rome by the Pope. A similar occurrence took place at Sienna. The cathedral church having been repeatedly damaged by lightning, a metallic rod was erected, but this was regarded with much terror by the inhabitants, who requested that the "heretic rod" might be taken down. On the 10th April, 1777, however, a thunder-storm occurred, and a heavy discharge of lightning fell on the tower without doing the slightest damage. The people now began to regard the heretic rod with more confidence, and it is worthy of remark that the church has never suffered from lightning since its erection.

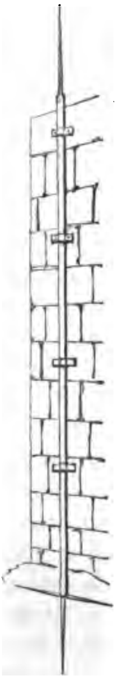
In the application of metallic rods it will be borne in mind, that a building or a ship is a system of good and bad conductors generally alter-

nating without much method. A structure formed entirely of good conductors, such as an iron steam-boat, is perfectly safe from the attacks of lightning. So also a man in armour is safe during a thunder-storm, from the great conducting power of his covering. The application therefore of lightning conductors to buildings and shipping may be considered as effectual, if a somewhat similar conducting power be given to them throughout their mass.

In the erection of a lightning rod there are many conditions to be attended to: and *first*, with respect to the material employed; metal will of course be preferred to any other substance, on account of its superior conducting power. Metals, however, vary in conducting power to a very considerable extent. If the conducting power of lead be taken as 1, that of tin will be 2; or, in other words, tin conducts electricity twice as well as lead; iron nearly two and a half times as well, zinc four times, and copper twelve times. There is no doubt, then, that according to this comparison copper is the best material for lightning conductors. It is certainly more expensive than iron; but iron is liable to rust, and on account of

its low conducting power is more easily melted by a discharge of lightning than copper. An electrical explosion which only melts a copper wire of a given diameter, would entirely destroy an iron wire of twice that diameter.

In the *second* place, the conductor must form one unbroken line throughout its whole extent; this condition has been already sufficiently explained. In the *third* place, the metal composing the conductor must expose as great an extent of surface as possible, consistently with strength and durability. This is necessary on account of the great heating power of the electrical discharge, for the heat developed by a passing shock is four times as great when the quantity of electricity is doubled, and only one-fourth as great when the diameter of the wire is doubled. The conductors for buildings, recommended by Sir W. Snow Harris, consist either of wide bands of copper, or of copper pipes from one to two inches in diameter, the metal of which they are formed being about one-fifth of an inch thick. It is prepared in lengths of about ten fect, which are united by means of short intermediate pieces furnished with screws. The conductor is supported



against the wall of the building by means of coupling pieces, or rings, as shown in the figure. The upper extremity, which should project freely into the air, should be pointed somewhat like a bayonet; this pointed extremity may be about eighteen inches long, and three quarters of an inch in diameter: it is screwed into a solid plug fixed in the tubing. In cases where metallic vane-spindles, or other metallic points, exist, the rod may commence at once from them. The lower extremity of the rod has three divergent branches, which should pass under the surface of the ground, and if circumstances permit, be connected with a spring of water, a drain, or some other conducting channel. The conductor must be applied immediately to the part to be defended, and not at a short distance from it. It must be attached to the most prominent points of the building, and if the length be very considerable, the diameter of the rod should be increased. In

extensive ranges of buildings all the most prominent parts should be furnished with conductors, and so connected by horizontal lines running along the ridges of roofs, &c., that a discharge of lightning falling on the general mass of the building could not possibly find its way to the ground by any circuit of which the conductor did not form a part. On this account all great masses of metal in the neighbourhood of the conductor, which offer other possible lines of discharge, should be united with it; if this be done, no more of the discharge can pass in the direction of such masses than can be transmitted without damage.

In the United States of America thunder-storms are frequent; the houses are commonly covered with metal, and are rendered perfectly secure from lightning by connecting the metallic roof with the ground by means of the tin or copper gutters which serve to lead the water from the roof to the earth. For this purpose it is sufficient to solder to the lower end of the gutter a riband of sheet copper, two or three inches wide, and continue it out from the house until it terminates in moist ground. The upper ends of these gutters are generally soldered to the roof; but if they are not

in metallic contact, the two are joined by a slip of sheet copper. The only part of the house unprotected by this arrangement will be the chimneys; and in order to secure these it is only necessary to erect a short rod against the chimney, soldered at its lower end to the metal of the roof, and extending sixteen or twenty inches above the top of the flue.

It was long a favourite question as to how far the protecting power of a lightning rod extends. Leroy stated, in 1788, that a conductor protected a horizontal space around it equal to somewhat more than three times the height of the metal rod above the building to which it was attached. The physical section of the Academy of Sciences of Paris, on being consulted by the Minister of War in 1823, expressed their opinion that a lightning conductor protects around it a circular space of which the radius is equal to the height of the rod. Other French writers state that the protecting influence of a metallic conductor extends over a space the radius of which is equal to double the height of the rod above the highest point of the building or ship to which it is attached.

Such calculations as these seem to be founded on erroneous ideas as to the nature of a thunder-storm.

It has been already shown that the forces in operation are distributed over a great extent of surface, and that the point or points upon which the lightning strikes depends upon a peculiar electrical condition of the air between the clouds and the earth, and does not depend upon the presence of a metallic body projecting into the air. If the air in the immediate neighbourhood of a tall building or a ship be in that excited state which is favourable for a disruptive discharge, such a discharge will take place upon the building or ship; and if any damage results, its amount will depend upon the conducting power of those bodies; if the conducting power be low, if masses of metal alternate with bad conductors, the expansive action of the electricity will be exerted with fearful effect, as in the numerous cases already cited; but if, on the contrary, the building or the ship be armed with capacious metallic conductors properly arranged, such conductors will determine the course of the discharge, and convey it to the earth or to the sea without the slightest damage to the surrounding conducting bodies.

The examination of a few cases will show that a radius of protection in lightning rods does not exist

in nature. In May 1847 H.M. corvette *Dido*, furnished with Harris's complete system of conductors, was struck by lightning in the course of her passage to New Zealand, during a very severe thunder-storm, accompanied with heavy rain but with little wind. Soon after daybreak a vivid and fierce discharge fell, in a double or forked current, upon the main-royal-mast; one of the branches struck the extreme point of the royal yard-arm, and, in its course to the conductor on the mast, demolished the yard, and tore in small pieces, or scorched up, the greater part of the sail; the other part fell on the vane, spindle and truck, which last was split open.* In this case the conductor on the mast did not protect the yard-arm, and it was not until the conductor had, as it were, got complete possession of the electrical discharge that the protection became apparent; the lightning then freely traversed the whole line of the conductor, from the mast-head downward, without doing further damage. It vanished, as it were, in the sea, being effectually conducted through the ship, which, nevertheless, felt the shock through her whole frame. No one on board was injured; and the

* See the Engraving at p. 216.

conductor was considered by the officers to be "a complete safety-valve."

Sir W. Snow Harris, in reporting this case, alludes to the prejudice once so common, that lightning-rods *attract* lightning, and, therefore, are more dangerous than useful. It has been proved, he remarks, by a large accumulation of facts, that metallic bodies exert no active influence in attracting or drawing lightning aside from its chosen path. A metallic conductor presents to the lightning a passive line of less resistance than that in which it is about to move; so far the action of lightning-conductors may be within certain limits beneficial in preventing a discharge from falling or continuing in an inconvenient direction; but otherwise, they have really no attractive power proper to themselves in drawing it aside, their action is consequently purely passive; they operate in the way of rain-pipes, only in carrying off the discharge which falls on them. "They are rather the patients than the agents, and they can only so far defend the bodies to which they are immediately applied. It is, therefore, quite impossible to defend a yard with its attached sail by a conductor on the mast, should the course of the discharge be in that direction,

since we cannot dictate to the electrical agency how and in what way it shall approach the ship. Such projecting points are, therefore, liable to be assailed, as in the present instance, and we cannot possibly protect them except by perfecting the conducting power of the yard, which might prove troublesome and inconvenient to carry out as part of a general system, although still possible to be done."*

Other cases might be quoted to disprove the French theory of the radius of protection of lightning conductors. For example:—Many ships furnished with a lightning conductor on the mainmast only have been struck on the foremast, and severely damaged. An extensive range of buildings furnished with a conductor proceeding from the highest point directly to the ground may be struck at one of its lower summits, which, in fact, has happened on several occasions. Hence it is of importance in ships not to trust to a conductor on one of the masts only, and in ranges of buildings

* Abridged from a pamphlet by Sir W. Snow Harris, entitled "Remarkable Instances of the Protection of certain Ships of H. M. Navy from the destructive Effects of Lightning." Printed for private circulation.

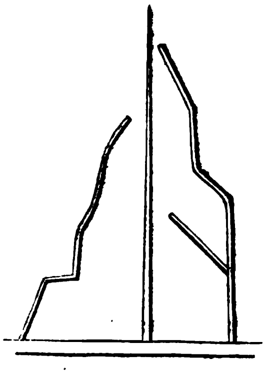
it is important to distribute connected conducting lines through them, in contact with pointed conductors rising into the air from different parts.

It was at one time thought necessary to insulate the conductor, either by enclosing it within glass tubing or by attaching it to the building with glass supports. This is quite unnecessary; for the electrical discharge never quits an easy line of transit, such as is furnished by a copper rod of sufficient size, to pass to other bodies out of such

line. For example, if metallic cramps be employed in the construction of a building, the

lightning striking such building would use these cramps as so many stepping stones to facilitate its descent to the earth, as in the case of St. Bride's Church, already noticed. But if a metallic conductor be erected, the lightning would entirely disregard the cramps, and descend by this the easiest and shortest conductor.

There are cases, however, in which a division of the charge takes place, a portion of the lightning bounding off from the conductor to other metallic bodies in connexion with the earth. If in the next figure the straight vertical line be the metallic conductor as before, and the bent lines portions of metallic water pipes, or other similar bodies passing near it to the earth; then, if the conductor be of small size, or terminate in a very dry soil, it will offer resistance to the discharge, and a division is then very likely to take place. Hence the necessity of connecting the



lightning conductors of a building with all other masses of metal which lead to the ground.

The division of the discharge into two parts is called the *bi-furcation*, and into three parts the *tri-furcation* of lightning. A case of bifurcation has already been narrated. The following is another instance of the same kind:—On the 14th August, 1779, a church at Genoa, furnished with a metallic conductor, was struck by lightning. The conductor commenced from a stout iron rod tipped with a gilded copper point, projecting from the top of the bell tower three feet into the air, and at its lower part was led out through a window over the roof of the church to the ground. Before the lightning struck the church it bifurcated, one of the discharges fell on the conductor, split open the copper point, and was then conducted to the earth without further damage. The other explosion struck the porch at a distance from the conductor, descended into the church, and did some damage. Several persons who were in a room over the porch felt a violent shock, and some were thrown down but not hurt.

The following is a case of trifurcation:—On the 17th June, 1781, the Poorhouse at Hecking-

ham was struck by lightning, which damaged one of the extreme corners of the building, at a distance of nearly seventy feet from the pointed metallic conductors, with which the house was furnished. The house consisted of a central range of buildings and two flanks, somewhat in the form of the letter H. There were eight chimneys, each furnished with a conductor. The flash appears to have divided into three parts; one part struck on one of the conductors and was carried off; a second fell on the extreme point of the building and set it on fire; a third fell on the earth immediately in front of it. An observer who witnessed the descent of the lightning, saw it divide into "three fire-balls," as he called them.

Such cases as these beautifully illustrate the value of metallic conductors; for instead of the ruin and devastation occasioned by a discharge of lightning in their absence, the damage is very trifling, and even this might be altogether avoided by continuing the conductors in horizontal lines from the principal conductors, in such a way as to bind the whole range of buildings into one complete metallic system.

The value of conductors is also well illustrated

in the following case:—In May, 1837, an electrical explosion divided upon two adjoining houses in Chowringhee, in the East Indies; one of the houses not having a lightning rod was struck and damaged, whilst the adjoining house, furnished with a conductor, escaped, although a portion of the discharge fell on it with great violence. The occupant of the unprotected house, while walking in the verandah, saw the lightning strike his neighbour's conductor, and at the same time strike his own house. The distance between the conductor and the damaged house was sixty-six feet.

It will be seen from the foregoing details that the application of lightning conductors to buildings presents little or no difficulty. The application of metallic conductors to ships is, however, a far more difficult and complicated task, "because the masts and rigging, the only parts to which they can be applied, are both subject to frequent change and derangement. The masts, although erect, consist of distinct portions; these it is often requisite to move one on the other, and sometimes to remove altogether. To construct and apply a conductor to a ship, such as may be permanently fixed, of great capacity, and require no handling or attention

on the part of the crew, would seem at first a problem of no small difficulty."

Soon after the application of metallic conductors to buildings, attempts were made to furnish ships with a similar means of protection. In the year 1762, Dr. Watson recommended to the Admiralty a form of conductor, consisting of long links of copper rod, about one-fourth of an inch in diameter, united by small eyes turned in each extremity: the chain thus formed being tied to a rope, and thus attached to the mast-head, whence it proceeded over the side of the ship into the sea. This suggestion was immediately adopted, and a chain conductor supplied to every ship in the royal navy. It was packed in a box, to be used as occasion required.

Such a conductor would doubtless contribute to the preservation of a ship, supposing it were in its place during a thunder-storm, and that the stroke of lightning fell on the mast to which it was applied. It is, however, impossible to ensure either of these conditions. A storm has often overtaken and damaged a ship before the conductor could be

unpacked,* and the lightning has struck and shivered the foremast, to which no conductor was applied, avoiding the mainmast, which was protected. Besides this, the links of a chain-conductor offer more resistance to the passage of the electric fluid than a continuous band or line of metal: hence the links are liable to be shattered, and the metal to be fused. This has happened in several cases. For example, on the 26th January, 1838, lightning fell on H. M. ship *Dublin*, at Rio de Janeiro. Several portions of the linked copper conductor, with which the ship was furnished, were melted, and fell on the deck; other parts, which remained attached, appeared as if they had been exposed to a very fierce heat.

In the year 1824, the French employed wire conductors, twisted together in the form of ropes. They were applied in the form of rigging, from the vane-rod to the ship's side, where they were connected with a plate reaching to the sea. There are many objections to conductors of such small dimensions applied as rigging, and dependent on the sailors for their due application. Without stopping to

* This happened in the case of the New York packet, quoted at p. 80.

point out their inefficiency as mere conductors, the circumstance of arranging, displacing, and altering their position according to the varying circumstances of the ship, is of itself a sufficient objection. "Let any one picture to himself a heavy gale, a pitchy dark night, squalls of wind with lightning and thunder,—a very common case,—and that it becomes necessary to make certain changes in the masts and sails; as, for example, to strike the top-gallant masts and get them on deck." In this case the men are necessarily exposed aloft, and have to disengage the conductor and the truck to which it is attached. If, at the time, the ship be struck by lightning, the men must either be killed or seriously hurt. Indeed there are many cases which show the great danger of handling such conductors in thunder-storms. Three seamen, in the act of applying a linked conductor on board one of the American ships-of-war in the Mississippi, were struck dead.

In the year 1821, Sir W. Snow Harris submitted to the Lords of the Amiralty a plan for protecting ships from the ravages of lightning. This plan was founded on a scientific as well as a technical knowledge of the exigencies of the case,

and consisted in the application of conductors under a form so capacious and so permanently fixed, as to render them an integral part of the vessel, and independent of the crew under all circumstances. According to his plan the masts themselves are converted into lightning conductors, "by incorporating with them a double set of copper plates, in such a way as to produce an elastic metallic line along their surface, capable of resisting any strain which the spars themselves could support; and, finally, to connect these plates with bands of copper leading through the side under the deck-beams, and with the large bolts leading through the keels and keelson; and including, by other connexions, all the principal metallic masses employed in the construction of the hull; thus rendering the ship quite safe from any discharge of lightning which would be likely to fall upon it, by bringing the whole fabric as nearly as possible under the conditions most favourable to perfect security."

The bands of copper employed for these conductors are four feet in length, and vary from one and a half to five inches in width, and from one-eighth to one-sixteenth of an inch in thickness.

Holes are drilled in them at distances of six inches apart, by which they are secured to the masts by short copper nails. A shallow groove is ploughed out in the after side of each mast, and the plates being slightly curved, to suit the form of the mast, are properly fixed into these grooves, so that they are closely incorporated with the round of the spar, and form, as it were, a portion of it. The plates are inserted into the grooves in a double series, placed so as to allow the joints of every two plates to fall upon the centre of another plate, immediately above or below it. The method of fixing these plates is extremely expeditious and easy, whilst the expense bears a very small proportion to the value of the ship, and quite vanishes when we consider how important is the protection afforded. "The cost of a first-rate, with all her stores, is not less than 170,000*l.*; she carries full nine hundred men, and she is intended for the defence of one of the greatest maritime nations which has ever existed. Now, the protection of this splendid machine against one of the most fearful calamities to which she is exposed, may be attained at a cost of less than 100*l.*, *i. e.* the expense of labour in fixing the conductors to the

ship, and the loss upon the wear of the copper material, which is always reconvertible, and of a constant value. Her Majesty's navy once furnished with such conductors, as an integral part of the ship, little or no further expense will be requisite, as the hulls will be always ready to receive masts fitted with the same conductors which have been already used in other ships, whose services have for the time ceased; it is hence a mere affair of transfer from ship to ship."

It is not necessary to follow out the minute details given by Sir W. Snow Harris, for fitting these conductors to the different parts of war and merchant ships. Those who require further information, can consult his able treatise on the subject. The principle upon which this system of fixed and continuous metallic conductors rests has been sufficiently explained, and a few details illustrative of the complete success of this system will be of more interest to the general reader. These conductors have been adopted in the British navy, and during more than twenty years ships furnished with them have navigated almost every clime, and have encountered thunder-storms of various degrees of severity. Many ships have been struck by

lightning, and yet no damage has been done: for by means of these conductors the terrific lightning has been in most cases reduced to a harmless and insensible current, of momentary duration, running down the conductor into the sea, as water would run down a pipe placed so as to conduct it; and in those cases where the ship has been struck so severely, that, to use the expressive language of one of the officers, "she actually reeled under the force of the discharge," instead of the wreck and devastation which would certainly follow the absence of conductors, and, probably, the presence of inefficient ones, no sort of damage has occurred.

In proof of this a few of the numerous cases which have been published may be quoted. In a communication to the Nautical Magazine, Captain Sullivan, R.N., describes the effects of a discharge of lightning which fell on H. M. ship *Beagle*, at Monte Video, and which he witnessed during his period of duty on deck. "Having," says he, "been on board His Majesty's ship *Thetis* at Rio de Janeiro a few years since, when her fore-mast was entirely destroyed by lightning,* my attention was

* This case is described at page 144.

always very particularly directed to approaching electrical storms, and especially on the occasion now alluded to, as the storm was unusually severe. The flashes succeeded each other in rapid succession, and were gradually approaching; and as I was watching aloft, the ship became apparently wrapt in a blaze of fire, accompanied by a simultaneous crash, which was equal, if not superior, to the shock I felt in the *Thetis*. One of the electrical clouds by which we were surrounded had burst on the vessel, and as the mainmast at the instant appeared to be a mass of fire, I felt certain that the lightning had passed down the conductor on that mast. The vessel shook under the explosion, and an unusual tremulous motion could be distinctly felt. As soon as I had recovered from the surprise of the moment, I ran below to state what had happened, and to see if the conductors had been affected, when just as I entered the gun-room, Mr. Rowlett, the purser, ran out of his cabin (along the beam of which a main branch of the conductor passed), and said he was sure the lightning had passed along the conductor, for at the moment of the shock he heard a sound like rushing water along the beam. Not the slightest

ill consequence was experienced, and I cannot refrain from expressing my conviction that, but for the conductor, the results would have been serious."

A terrific explosion of thunder and lightning fell on the mainmast of the *Fisgard* on the evening of Saturday, the 26th September, 1846, whilst at anchor in the Nisqually river, in the Oregon territory.

From a careful review of the official and other documents relating to this case, it is apparent that the ship experienced one of those bifurcated discharges of lightning so frequently observed at the instant of a vivid and intense explosion falling on elevated bodies. The current of lightning evidently divided on approaching the mast, and struck simultaneously on the vane-spindle aloft, and on the lower mast, from three to thirteen feet above the deck,—as represented in the frontispiece to this volume.

The fact is thus recorded in the ship's log:—

Saturday, 26th September, 1846, P.M. 7. 45.

"The mainmast was struck by lightning, the electric fluid passing down the conductor and out

on both sides of the ship with a very loud explosion, but doing no injury."

The following statement includes the substance of the official letter relative to this case, forwarded by the Captain of the *Fisgard* to the Lords Commissioners of the Admiralty:—

On the 26th inst. at 7.45 P.M., the mainmast was struck by lightning: a very vivid flash, succeeded by a loud report, as if a broadside had been fired from each side of the ship, was observed by the senior lieutenant, then on deck, to strike the mainmast. The next morning, on examining the conductor along the mast, the vane-spindle was observed to have been fused at the point, and blackened one-third of the way down. There were no marks on the conductor of the royal or topgallant masts, except at the part covered by the cap, where it appeared blackened, and the heads of the nails slightly fused. The conductor on the main-topmast exhibited no marks whatever. The conductor on the mainmast, low down, was found to have been started from the mast in three places—one just above the spider hoop of the awning, another just below this, and another below this again: (according to the surgeon's

meteorological report, the respective distances were, twelve and a half, seven and a half, and two and a half feet above the upper deck.) The plates of copper forming the conductor were separated at the lowest point, and thrust, as it were, asunder; the edge of the groove in which the plates were laid was slightly rent by the starting of the plates, thereby causing two or three splinters to fall on the deck at the time of the discharge. The electrical current having passed down the mainmast, took the direction of the branches to the bolts through the side,—one leading through the boatswain's cabin, and the other through the midshipmen's berth. The branch conductors in this ship, instead of leading directly to the copper sheathing, near the water's surface, as originally proposed, had been led out above it, to two bands of copper passing down externally over the ship's side; these bands were also started at the ends in contact with the termination of the through bolts, the copper sheathing covering the other extremity of the band was bulged outward. It is also stated that a boatswain's mate, standing abaft the mainmast, on the starboard side, was knocked down, and that one of the midshipmen, also

on the starboard side, on the main-deck near the mast, felt himself thrust, as it were, aside, but without falling. Dr. Dunn, the surgeon of the *Fisgard*, remarks in his report, that there is some difficulty in determining how far the boatswain's mate was struck down by the direct influence of electricity; he appears rather to have fallen down by the concussion and panic of the instant. The senior lieutenant, standing close by, and within three yards of the mainmast, experienced no effect whatever; and it is worthy of remark, that one of the gentlemen in the midshipmen's berth was leaning at the time of the shock with his elbow resting against the thin batten or casing covering the conductor, his head at the same time resting on his hand, so that it was within a few inches of it. He describes the effect as being similar to the report of a pistol fired close to the ear, but says he did not experience any electrical shock, or any other inconvenience. Captain Duntze concludes his letter by observing: "Mr. Rodd, the senior Lieutenant, gives it as his opinion, from the severity of the shock, that had it not been for the efficiency of the conductors, the mainmast must have been totally destroyed, and much serious

damage have occurred, in which opinion I fully coincide."

This storm appears to have been of no ordinary kind; several of the pine-trees on the neighbouring land were found to have been struck by the electrical discharge, and set on fire. The people on shore employed on work for the service of the ship, state that the lightning repeatedly struck the ground in all directions; the ship appeared covered with fire, and the whole atmosphere in a general blaze, with terrific bursts of thunder. According to Dr. Dunn's intelligent Meterological Report, "Thunder and lightning are not frequent in this part of the world, but it would appear, that towards the end of autumn, when the weather begins to break, the periodical change is ushered in by electrical phenomena." On this occasion the day had been dark and gloomy, with heavy falls of rain. The thunder-clouds were observed by the first lieutenant gradually to approach the ship, with frequent discharges of lightning. The effect was such, when the explosion fell on the mast, as to cause a sort of momentary panic, attended by a death-like silence. Some of the seamen who were smoking, involuntarily took the

pipes from their mouths, and laid them down, and the band, which was performing some music at the time on the quarter-deck, suddenly ceased. The first impulse was to open the cocks and let water into the ship for the use of the engines, under an impression that, from the extreme and awful violence of the discharge, something serious must have happened.

Such are the principal facts in the history of this interesting case, and which are most important as furnishing conclusive evidence of the protection to be derived from continuous and capacious lightning conductors on shipboard, applied in the way we have described. Here is indisputable evidence, that as powerful a discharge of lightning as can be well imagined, fell with force directly on the mainmast of the *Fisgard*, which expended all its fury on the conductor, and was, by its protective influence, led securely to the sea, without the slightest damage or inconvenience. We trace it from the points on which it first struck, down to the very sea in which it finally vanished, and we find the ship unharmed and still efficient amidst the blaze and crash of the most terrible element in nature.*

* Abridged from Sir W. Snow Harris's pamphlet.

AURORA BOREALIS, SEEN IN THE BAY OF ALTEN.

CHAPTER VIII.

ATMOSPHERIC ELECTRICITY—APPARATUS FOR OBSERVATIONS ON—THE ELECTROMETER—METHOD OF USING—ORDINARY ELECTRICAL STATE OF THE AIR—DIURNAL VARIATION OF THE ELECTRICITY—ANNUAL VARIATION—LOCAL VARIATIONS—DISTRIBUTION OF ELECTRICITY IN THE AIR—ELECTRICITY OF THE AIR IN CLOUDED WEATHER—THE AURORA BOREALIS—ELECTRICAL ORIGIN OF—GENERAL DESCRIPTIONS OF—ITS COLOURS—ITS ACTION ON THE MAGNETIC NEEDLE—HEIGHT OF THE AURORA—SOUND SAID TO BE PRODUCED BY—BEAUTIFUL APPEARANCE OF THE POLAR SKY.

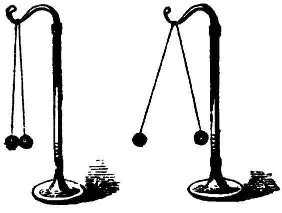
One of the consequences of Franklin's capital experiment on the identity of electricity and lightning, was the discovery of the fact that electricity exists in the air in other states than that of the thunder-storm. Franklin erected in his house at Philadelphia a pointed iron rod, which he could insulate at pleasure. This rod was connected with a system of small bells, which alternately attracted and repelled their hammers when electrified. Whenever a cloud charged with electricity passed over his house near enough to affect the

conductor, the bells would ring, and inform the philosopher that a supply of the electric fluid was waiting his pleasure.

By means of this apparatus Franklin concluded that the electricity of the clouds was sometimes positive, and sometimes negative, but oftener negative. This scientific apparatus, however, was not, in this early stage of electrical science, calculated to produce satisfactory results. In the year 1792, Mr. Read described to the Royal Society a far more perfect apparatus for observing the electricity of the atmosphere. It consisted essentially of an iron rod, from twenty to twenty-five feet in length, erected at the top of the building in which the observatory was placed, and carefully insulated at the points where it met the roof and other parts of the building. The lower parts of this rod were connected with an electroscope, by means of a chain or bar capable of being removed at pleasure. A moveable communication was provided between the pointed rod and a metallic bar continued to the ground, so that in cases of thunder-storms, or at times when the electricity of the air was so strong as to be attended with danger, it could be allowed to escape to the earth

by connecting the pointed rod with the conductor. In observing the electric state of the air when it was strongly charged, the bar connecting the pointed rod with the conductor could be brought so near the latter as to allow the chief part of the electricity to pass through it to the ground; at the same time the connexion of the electroscope with the pointed rod being preserved, a sufficient quantity of electricity would affect it to indicate the kind of electricity with which the air was charged.

The *electroscope* or *electrometer* depends upon the simple laws of attraction and repulsion already explained. If two pith balls, attached to the ends of a thread, be suspended on an insulating stand, they will of course hang down in contact, as shown in the first figure; but if we present an excited glass tube to them they will first be attracted, and both will acquire a

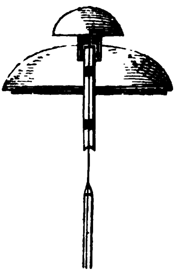


charge of electricity of the same kind. On gently withdrawing the tube, the balls will no

longer hang down as in figure 1, but will repel each other as shown in the second figure. While in this state of repulsion the kind of electricity with which they are charged can be determined by bringing near them an excited glass rod or a stick of resin; if the repulsion increases with the glass the electricity is vitreous or positive, if it increases with the resin, it is resinous or negative. Of course, if the repulsion increases with the glass it will be destroyed by the excited resin, or if increased by the resin, it will be destroyed by the glass.

A very useful form of electrometer has been constructed on this principle. It consists of two slips of gold leaf, half an inch wide, and from two to three inches long, suspended by means of a wire in a glass cylinder. The wire passes through a glass tube attached to the bottom part of a brass cap, which screws into the centre of a circular plate

covering the cylinder, as shown in the accom-



panying improved form of cover to the instrument.

By means of this instrument a very slight state of electrical disturbance can be detected. If the cover of the instrument be gently struck with a silk handkerchief the leaves will immediately start asunder, showing strong repulsion resulting from electricity set free by the friction of the metal and the silk. If the cover be blown upon by a pair of bellows the leaves will also diverge, in consequence probably of the friction of the air upon the metal.

An instrument of this sort connected with a rod springing up into the atmosphere, as in Mr. Read's apparatus, will nearly always indicate the presence of electricity. When the leaves are diverging, an excited rod of glass or a stick of resin held a short distance over the cover of the electrometer, will indicate the kind of electricity in the atmosphere. If glass causes the leaves to fall together, or diminishes the divergence, then the atmospheric electricity is *negative*; if it increases the repulsion it is *positive*.

By means of numerous observations with the apparatus just described, it was found that in clear weather, when there are no clouds, the atmosphere is always charged with positive electricity, while the surface of the earth is negative. The intensity of the electricity of the air varies at different hours of the day. It gradually decreases after midnight until a short time before sunrise, when the intensity continues stationary for a short time, and then begins slowly to increase. It goes on increasing for some hours after sunrise until it attains its maximum; it then begins to decrease, slowly at first, but afterwards more rapidly. This decrease continues for some time after the sun passes the meridian, when it ceases, and the electrical intensity is at a minimum. It then begins to increase, and attains another maximum some time after sunset. It then continues to decrease until midnight.

There is also an annual variation of the electrical intensity. The two daily points of greatest and smallest intensity decrease progressively from January to July, and increase from July to January. During winter the electricity of the air increases with the cold.

In common with other meteorological observations, the results which have been obtained at one place do not necessarily apply to another. A variety of local causes may exist to interrupt the uniformity. "Saussure's observations show that the positive electricity of the air has greatest intensity in the most elevated places, and in those which are best insulated. In the interior of buildings, under trees, in the streets, courts, and other enclosed and sheltered parts of towns, no free electricity is found in the air. In the midst of squares, and other open spaces in cities, on the quays, but more especially on bridges, it is even more intense than in an open flat country. In particular localities, such as Geneva, where fogs prevail which lie low, and are not converted into rain, the positive electricity of the air is most intense."

The negative electricity of the earth, and the positive electricity of the air near it, have a constant tendency to combine and neutralize each other. In clear weather, the air to the height of three or four feet from the ground is in its natural state without any signs of free electricity. Above this positive electricity begins to be found, and its intensity goes on increasing with the height.

The increase of electrical intensity with the height was ascertained in a very ingenious manner by Messrs. Becquerel and Breschet. They ascended the Great St. Bernard, and upon one of the small plains in the neighbourhood of the hospice extended a piece of gummed sarcenet, about ten feet long and seven feet wide, upon which they unrolled a silk cord interlaced with metallic wire, measuring about 250 feet in length. One of the ends of the thread was put in communication with the cap of an electrometer by means of a loose knot, and the other was attached to the shaft of an iron arrow, which was then shot into the air from a well-bent bow. The arrow as it rose in the air carried the thread with it, and detached it from the electrometer after it had completely unrolled. The straws of the electrometer separated more and more as the arrow rose, and so strong was the repulsion, that they struck the sides of the glass cylinder enclosing them. When the cord was detached, the instrument retained its charge of electricity, which was found to be positive. That the electricity was not produced by the friction of the arrow passing through the air, was proved by shooting it in a horizontal

direction, when no effect was produced upon the electrometer.

The electricity of the atmosphere in clouded weather, and in times of rain, hail, and snow, has been studied by M. Schubler, at Stuttgard, who arrived at the following conclusions, after a large number of observations:—

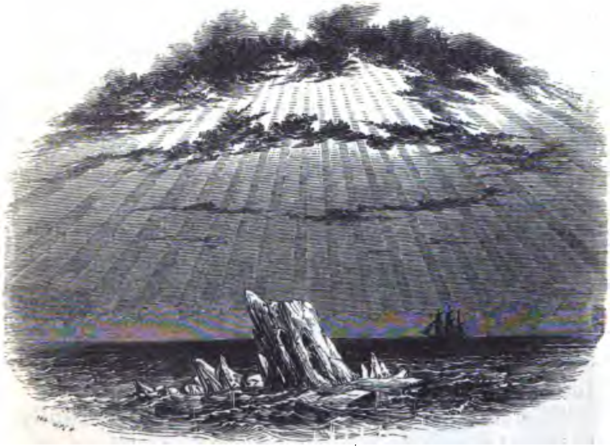
First.—That in stormy weather, in rain, hail, or snow, the electricity of the air is much more intense than at other times. Second.—That in such weather the electricity is sometimes positive and sometimes negative, and nearly as often the one as the other. Third.—That in such weather the electricity often undergoes sudden changes from positive to negative, and *vice versâ*. Fourth. —That in clouded weather, unattended by storm, rain, hail, or snow, the free electricity of the air is positive. Fifth.—That the intensity of this electricity is greater in winter than in summer.

The sources from which the air derives its electricity are still a matter of doubt and discussion among scientific men. Indeed, the subject of atmospheric electricity has advanced only a few steps since the time when Franklin first brought down electricity from the thunder-cloud.

The electricity of the atmosphere sometimes becomes visible under the most beautiful and fantastic displays of form, light, and colour, producing what is called the *Aurora Borealis*, or *Northern Lights*. This term has been applied to the phenomenon on account of the geographical character of the globe, which admits of its being much more frequently seen in the northern than in the southern hemisphere. In the latter the phenomenon bears the name of *Aurora Australis*. The term *Aurora Polaris* has been suggested as a more proper designation for both varieties.

The Aurora Borealis consists of beams or rays of light, and sometimes of arches or crowns. The rays generally move with greater or less velocity through the sky; the arches are sometimes single, while at other times several concentric ones appear. In the Shetland Islands these lights are called the *Merry Dancers*, where on clear evenings they mitigate the gloom of the long winter nights. "They commonly appear at twilight near the horizon, and sometimes continue in that state for several hours without any sensible motion; after which, they send forth streams of stronger light, which rise from the horizon in a pyramidal, undu-

lating form, shooting with great velocity up to the zenith, assuming columnar and other shapes,



AURORA AUSTRALIS.

and varying in colour from a reddish yellow to the darkest russet. At other times they cover the whole hemisphere with their flickering and fantastic coruscations. On these occasions their motions are amazingly quick, and they astonish the spectator with rapid changes of form. They

break out in places were none were seen before, skimming briskly along the heavens; then they are suddenly extinguished, leaving behind a uniform dusky track, which again is brilliantly illuminated in the same manner, and as suddenly left a dull blank. Some nights they assume the appearance of vast columns, exhibiting on one side tints of the deepest yellow, and on the other melting away till they become undistinguishable from the surrounding sky. They have generally a strong, tremulous motion from end to end, which continues till the whole vanishes. According to the state of the atmosphere, their columns vary." They sometimes assume the hue of blood, and then the superstitious observer sees in them the portents of war, pestilence, and famine.

The streamers of the Aurora can be beautifully imitated by passing a succession of electric sparks through a long glass tube from which the greater part of the air has been withdrawn by means of the air-pump. With a powerful electrical machine the effects are most brilliant, the whole tube being filled with flashes of light, the colour of which varies from that of the bright electric spark to a beautiful violet or purple. The

accompanying figures are intended to convey a faint idea of these effects. They show the transmission of continuous electrical streams through an exhausted cylinder of glass of above four inches in diameter, and upwards of six feet in length. When this long tube was moderately exhausted, and its extremities connected with the positive and negative conductors of a very powerful electrical machine, luminous streamers were produced, branching upon the sides of the tube towards the negative end. When the upper end was connected with the positive conductor, and the lower end with the negative, the currents appeared as in A; by reversing this arrangement the effect shown in B was produced. As the exhaustion

A. B.

was more complete, the distinction of the branches gradually become less, so that finally the whole interior surface of the glass was covered with a continuous mass of white light.*

Lieutenant Hood, in Captain Franklin's narrative, describes the several parts of the Aurora under the terms *beams*, *flashes*, and *arches*. The *beams* are small conical pencils of light, ranged in parallel lines, with their pointed extremities towards the earth, generally in the direction of the dipping needle. The *flashes*, which are sudden in appearance and seldom last long, seem to be scattered beams approaching nearer to the earth, because they are similarly shaped and infinitely larger. When the Aurora first becomes visible it is formed like a rainbow, the light of which is faint and the motion of the beams undistinguishable. It is then in the horizon. As it approaches the zenith it resolves itself at intervals into beams, which by a quick, undulating motion, project themselves into wreaths, afterwards fading away, and again brightening, without any visible expansion or concentration of matter. Numerous flashes are seen in different parts of the sky. That this

* Harris, Philosophical Transactions for 1834.

mass, from its short distance above the earth, would appear like an *arch* to a person situated at the horizon, may be demonstrated by the rules of perspective, supposing its parts to be nearly equidistant from the earth.

THE AURORA IN LAPLAND.

The Aurora does not always make its first

appearance as an arch. It sometimes rises from a confused mass of light in the east and west, and crosses the sky towards the opposite point, exhibiting wreaths of beams, or coronæ boreales, in its way. An arch, also, which is pale and uniform at the horizon, passes the zenith without displaying any irregularity or additional brilliancy. Three arches have been seen together very near the northern horizon, one of which exhibited beams, and even colours; but the other two were faint and uniform.

With respect to the *colours* of the Aurora, Lieutenant Hood says:—"The colours do not seem to depend on the presence of any luminary, but to be generated by the motion of the beams, and then only when that motion is rapid and the light brilliant. The lower extremities quiver with a fiery red colour, and the upper with orange. Violet has been seen in the former."

Other observers describe the colours of the rays or beams as steel-grey, yellowish-grey, pea-green, celandine-green, gold-yellow, violet-blue, purple, sometimes rose-red, crimson-red, blood-red, greenish-red, orange-red, and lake-red; some of the beams appear as if tinged with black,

and resemble dense columns of smoke. The arches are sometimes nearly black, passing into violet-blue, grey, gold-yellow, or white, bounded by an edge of yellow.

AURORA AUSTRALIS.

Mr. Ihle, an officer of the English Copper-mine Company at Kaafjord, near Alten, in Finmark, describes the northern lights as making their appearance, for the most part, over the western and north-western, and over the eastern and north-eastern horizon; rarely in the due north, and still more rarely over the southern horizon. The form of the northern lights is sometimes in stripes, and that either with a uniform division of

the light, or in bands with parallel streaks; and sometimes in bundles of rays, either ranged in certain lines next one another, or separated into undefined groups. The boundary of the stripes of light is sometimes sharp, sometimes obscure. More rarely than in the form of stripes and bundles of rays, the aurora sometimes appears in the form of undefined luminous clouds. The *black* rays of the northern lights—namely, sharply bounded stripes, surrounded by masses of light, which, however, are quite detached from them, are a not unfrequent but extremely striking phenomenon. Changes of temperature in the atmosphere generally stand in connexion with the appearance of brilliant northern lights; and thus a dry cold occurs after northern lights, emanating from the eastern horizon; while storms and snow, with diminished cold, follow the western aurora. Frequently, however, the northern lights from the east and west appear simultaneously, without the one or the other gaining the mastery, and then unsettled weather ensues. A variation of the magnetic needle generally follows the appearance of the aurora; in the case of the eastern aurora, the north pole of the needle is turned

eastwards, and in that of the western, westwards. A difference of height has been distinctly observed, though measurements were not practicable. The rays of the aurora were sometimes visible below the clouds, and were occasionally even lower than the abruptly rising acclivity of the valley. The lower the aurora, and the nearer the zenith, so much the more powerful was its influence on the magnetic needle. There appears also to be a certain connexion between the occurrence of storms and the appearance of the northern lights. In the case of violent storms occurring in sudden gusts, the northern lights are almost always in a state of flickering, rapid movement; and while at the periods of the greatest evolution of light the storm is generally much diminished, it is renewed in all its strength when the brilliancy of the aurora fades.

A very extensive series of observations on the Aurora Borealis, was made between September 1838 and April 1839, by the scientific commission sent by the French Government to explore the North Seas. These observations were directed by M. Lottin, and were made at Bossekop, in the Bay of Alten, on the coast of West Finmark. In

their published form they occupy a large volume; but it will be sufficient for our purpose to select a few of M. Lottin's general recapitulatory remarks.

The first appearance of the aurora was generally noticed between the hours of four and eight o'clock in the afternoon, behind the upper edge of a light sea fog, which almost constantly prevailed in the bay; this illumined edge gradually assumed the form of an arc of pale yellow light, with diffused edges, the extremities resting on the horizon. This arc enlarged upwards more or less slowly, its highest point being always on the magnetic meridian, or nearly so. The luminous portion of the arc was regularly divided by dark streaks, which formed it into a system of rays alternately extending and contracting, sometimes slowly, at other times instantaneously, darting out, increasing and suddenly diminishing in brightness. The lower parts of the rays were always the brightest. The length of the rays was very various; they converged to that point of the heavens indicated by the direction of the southern pole of the dipping-needle, or, by intersecting, formed the summit of a majestic dome of light. The arc would then

gradually extend towards the zenith, and appear to undergo an undulating kind of motion, in consequence of the rays from one extremity to the other, increasing excessively in brightness. This luminous effect would appear several times in

quick succession; and sometimes as soon as a wave of light had passed over all the rays, from

west to east, it would return in the contrary direction, producing the appearance of a riband or flag agitated by the wind, as shown in the figure. In some cases the arc would change its form, and assume that of a long sheet of rays returning into itself, forming several graceful curves, as shown in the frontispiece to this chapter. The rays would vary suddenly in brightness, sometimes exceeding that of stars of the first magnitude; then rapidly darting out, the curves formed like the folds of a serpent, and often of various colours, the lower part a blood red, the middle a pale emerald green, and the remainder its usual clear yellow. These colours were beautifully transparent, but occasionally they would fade and disappear either slowly, or suddenly. Then the fragments of the arc would unite, and continue to move upwards towards the zenith as before.

While the waves of light already mentioned were passing through the rays, new arcs were often formed in succession: as many as nine have thus been observed, their ends resting on the horizon. Sometimes two or more of these arcs would unite, and form a large zone across the heavens, becoming fainter after passing the zenith, and vanishing

towards the south. This zone, however, in some cases, extended from east to west; and, uniting with other rays from the south and north, formed the *boreal corona*—an appearance evidently due to the effect of perspective, for an observer placed at the same moment at a certain distance to the north or south would see only an arc. The corona seldom lasts more than a few minutes, and in many auroras is not seen at all.

The fleeting and fantastic lights of the aurora seem to be under the control of terrestrial magnetism, as noticed above. Captain Franklin made an extensive series of observations on this subject during his winter residence at Fort Enterprise, and his results agree with those of several other observers. In Franklin's observations, a horizontal compass was placed in a firm sheltered stand, fixed to the back wall of the house at Fort Enterprise, three feet above the ground, on a northern exposure; and a dipping needle was similarly fixed at the distance of forty feet. There was no iron near either of them, and the house stood on a sand-hill.

The motion communicated to the needle by the aurora was neither sudden nor vibratory. Some-

times it was simultaneous with the formation of arches, prolongation of beams, or certain other changes of form or action of the aurora. But generally the effect of these phenomena upon the needle was not visible immediately, but in about half an hour, or an hour, the needle had attained its greatest deviation. From this, its return to its former position was very gradual, seldom regaining it before the following morning, and frequently not until the afternoon, unless it was expedited by another arch of the aurora operating in a direction different from the former one.

"The arches of the aurora most commonly traverse the sky at right angles to the magnetic meridian, and the deviations from this direction were not rare; and I am inclined to consider that these different positions of the aurora have considerable influence upon the direction of the needle. When an arch was nearly at right angles to the magnetic meridian, the motion of the needle was towards the west; this westward motion was still greater when one extremity of an arch bore about 59° to the west of the magnetic north. A westerly motion also took place when the extremity of an arch was in the true north, or about 36° to the

west of the magnetic north. A contrary effect was produced when the same end of an arch originated to the southward of the magnetic west. In these cases the motion of the needle was towards the east. In one instance only a complete arch was formed in the magnetic meridian; in another, the beam shot up from the magnetic north to the zenith; and in both these cases the needle moved towards the west.

"The needle was most disturbed on February 13, P.M. at a time when the aurora was most distinctly seen passing between a stratum of clouds and the earth, or at least illuminating the face of the clouds opposed to the observer. This and several other appearances induced me to infer that the distance of the aurora from the earth varied on different nights, and produced a proportionate effect on the needle. When the light shone through a dense hazy atmosphere, when there was a halo round the moon, or when a small snow was falling, the disturbance was generally considerable; and on certain hazy cloudy nights the needle frequently deviated in a considerable degree, although the aurora was not visible at the time. Our observations do not enable us to decide

whether this ought to be attributed to an aurora concealed by a cloud or haze, or entirely to the state of the atmosphere. Similar deviations have been observed in the day-time, both in a clear and cloudy state of the sky, but more frequently in the latter case. Upon one occasion the aurora was seen immediately after sunset, whilst bright daylight was remaining. A circumstance to which I attach some importance, must not be omitted. Clouds have been sometimes observed during the day to assume the forms of the aurora; and I am inclined to connect with these clouds the deviation of the needle, which was occasionally remarked at such times. An aurora sometimes approached the zenith without producing any change in the position of the needle, as was more generally the case: whilst at other times a considerable alteration took place, although the beams or arches did not come near the zenith. The aurora was frequently seen without producing any perceptible effect on the needle. At such times its appearance was that of an arch, or a horizontal stream of dense yellowish light, with little or no internal motion. The disturbance in the needle was not always proportionate to the agitation of the aurora, but it was

always greater when the quick motion and vivid light were observed to take place in a hazy atmosphere. In a few instances the motion of the needle was observed to commence at the instant a beam darted upwards from the horizon; and its former position was more quickly or slowly regained, according to circumstances. If an arch was formed immediately afterwards, having its extremities placed on opposite sides of the magnetic north and south to the former one, the return of the needle was more speedy; and it generally went beyond the point from whence it first started."

The scene of the aurora was long supposed to be situated at a very great altitude. Euler estimated its distance at some thousands of miles; others have fixed its place at a few hundred miles; and others, again, much lower. The question, however, was settled by M. Biot, from whose observations it appears that the apparent place of the aurora in relation to celestial objects is not fixed; that its altitude and azimuth do not undergo those hourly changes to which heavenly bodies are subject; and that they undergo no motion, in reference to the zenith or horizon, such

as would be produced by the diurnal rotation of the earth. It must, therefore, be considered as proved, that the aurora borealis is a phenomenon confined to the limits of an atmosphere, and frequently coming very near the surface of the earth. Thus, Captain Franklin, while wintering at Fort Enterprise, says, "The important fact of the existence of the aurora at a less elevation than that of dense clouds, was evinced on two or three occasions this night (13th February, 1821), and particularly at 11h. 50m., when a brilliant mass of light, variegated with the prismatic colours, passed between an uniform steady dense cloud and the earth, and in its progress completely concealed that portion of the cloud which the stream of light covered, until the coruscation had passed over it, when the cloud appeared as before." Captain Parry, in his third voyage, notices a still more remarkable appearance of this kind. About midnight, on the 27th January, the aurora broke out in a single compact mass of brilliant yellow light, appearing only a short distance above the land. "This mass of light, notwithstanding its general continuity, sometimes appeared to be evidently composed of numerous pencils of rays, compressed,

as it were, laterally into one, its limits both to the right and left being well defined, and nearly vertical. The light, though very bright at all times, varied almost constantly in intensity, and this had the appearance (not an uncommon one in the aurora) of being produced by one volume of light overlaying another, just as we see the darkness and density of smoke increased by cloud rolling over cloud. While Lieutenants Sherer and Ross, and myself, were admiring the extreme beauty of this phenomenon from the observatory, we all simultaneously uttered an exclamation of surprise at seeing a bright ray of the aurora shoot suddenly downward from the general mass of light, and *between us and the land*, which was there distant only three thousand yards. Had I witnessed this phenomenon by myself, I should have been disposed to receive with caution the evidence even of my own senses, as to this last fact; but the appearance conveying precisely the same idea to three individuals at once, all intently engaged in looking towards the spot, I have no doubt that the ray of light actually passed within that distance of us."

It is scarcely possible to contemplate the Aurora

Borealis without associating *sound* with its lively coruscations and bursts of light; and there is some evidence to show that peculiar noises do occasionally accompany these phenomena. Nairne states that when the polar lights were véry bright, he has heard a hissing and whizzing noise. Cavallo describes it as a cracking noise; Giesecké, who resided in West Greenland, says, "The polar lights sometimes appear very low, and then they are much agitated, and a crashing and crackling sound is heard, like that of an electric spark, or the falling of hail." In Norway, according to Captain Brooke, the noise which accompanies the polar lights is like that of a rushing wind. Gmelin gives an interesting account of the aurora in Siberia, and of the noises which accompany it. "These northern lights," he says, "begin with single bright pillars, rising in the north, and almost at the same time in the north-east, which, gradually increasing, comprehend a large space of the heavens, rush about from place to place with incredible velocity, and finally almost cover the whole sky up to the zenith. The streams are then seen meeting together in the zenith, and produce an appearance as if a vast tent was

expanded in the heavens, glittering with gold, rubies, and sapphires. A more beautiful spectacle cannot be painted: but whoever should see such a northern light for the first time, could not behold it without terror; for, however fine the illumination may be, it is attended, as I have learned from the relation of many persons, with such a hissing, cracking, and rushing noise throughout the air, as if the largest fireworks were playing off. To describe what they then hear, they make use of the expression *spolochi chodjat:* that is, 'the raging host is passing.'" The hunters, who pursue the white and blue foxes in the confines of the Icy Sea, are often overtaken in their course by these northern lights. Their dogs are then so much frightened, that they will not move, but lie obstinately on the ground till the noise has passed.

Mr. Ihle has on several occasions heard a sound from the aurora. On the evening of the 28th January, 1840, he says, "There was distinctly heard a noise corresponding to the movement of the rays of light, and resembling the rustling of silk stuffs. The stillness which prevailed in the air at the time, and which was of rare occurrence, left no doubt about the matter." Again, on the

evening of the 22d March in the same year, the weather being calm and serene, northern lights were observed in thin fine stripes of light across the heavens from west to east. In the west and south-west, very bright, peculiar looking, yellowish green, luminous clouds proceeded from the horizon upwards, constantly changing in their form and in the intensity of their light. At the instant of the greatest development of light, viz., when the luminous cloud was near the zenith, there was a sound heard, resembling the rustling of straw or of cloth made of silk. On the 21st November in the same year, at 5 o'clock P.M., the weather being calm, "the atmosphere had cleared up, and rays of light shot simultaneously from the west and east horizon with the greatest brilliancy; at the zenith they whirled themselves round in a circle and formed crowns of light. A soft rushing was at the same time audible."

Although our modern Arctic travellers, Scoresby, Parry, Franklin, Richardson, Hood, and Back, had frequent opportunities of witnessing grand displays of the aurora, yet they never heard any sound accompanying it, although they do not dispute the testimony of older travellers. Thus

Franklin says:—"I have not heard the noise ascribed to the aurora, but the uniform testimony of the natives, and of the residents in this country, induces me to believe that it is occasionally audible." Parry frequently listened for sounds from the polar lights, but never heard any. Hood says:—"We repeatedly heard a hissing noise, like that of a musket-bullet passing through the air, which seemed to proceed from the aurora; but Mr. Wentzel assured us that this noise was occasioned by severe cold succeeding mild weather, and acting upon the surface of the snow previously melted in the sun's rays. The temperature of the air was then — 35°; and in the two preceding days it had been above zero. The next morning, it was —42°, and we frequently heard a similar noise. Mr. Hearn's description of the noise of the aurora exactly agrees with that of every person who heard it. It would be an absurd scepticism to doubt the fact any longer, for our observations have rather increased than diminished the probability of it."

Professor Hanstein accounts for the contradictory evidence of such distinguished observers by supposing that since the beginning of this

century we have arrived at one of the "great pauses" of this phenomenon, so that the present generation knows but comparatively little of it from personal observation.

Captain Lyon, while wintering with Captain Parry in Winter Island, endeavoured in vain to detect any sound accompanying the aurora. His description of the polar sky in winter is so beautiful that we quote the whole passage:—"To describe the colours of these cloudless heavens would be impossible; but the delicacy and pureness of the various blended tints excelled any thing I ever saw, even in Italy. The sun shines with a diminished lustre, so that it is possible to contemplate it without a painful feeling to the eyes, yet the blush colour which in severe frost always accompanies it, is, in my opinion, far more pleasing than the glittering borders which are so profusely seen on the clouds in warmer climates. The nights are no less lovely, in consequence of the clearness of the sky. The moon and stars shine with wonderful lustre, and almost persuade one to be pleased with the surrounding desolation. The Aurora Borealis does not appear affected by the brilliancy even of the full moon, but its light

continues still the same. The first appearance of this phenomenon is generally in showers of falling rays, like those thrown from a rocket, although not so bright; these, being in constant and agitated motion, have the appearance of trickling down the sky. Large masses of light succeeded next in order, alternating from a faint glow resembling the Milky Way, to the most vivid flashes, which stream and shoot in every direction with the effect of sheet lightning, except that after the flash the aurora still continues to be seen. The sudden glare and rapid bursts of these wondrous showers of fire render it impossible to observe them without fancying that they produce a rushing sound; but I am confident that there is no actual noise attending the changes, and that the idea is erroneous. I frequently stood for hours together on the ice to ascertain this fact, at a distance from any noise but my own breathing, and thus I formed my opinion; neither did I observe any variety of colour in the flashes, which were to my eye always of the same shade as the Milky Way and vivid sheet lightning. The stars which gleam through the aurora certainly emit a milder ray, as if a curtain of the finest gauze were

interposed. It is remarkable that whenever the weather is calm the aurora has a tendency to form an arch, at whatever position it may occupy in the heavens. On the 29th of this month, [December, 1821] we were particularly gratified by a beautiful exhibition of this kind at near midnight. A perfect arch was formed to the southward, stretching from east to west, its centre elevated about two degrees above the horizon. The night was serene and dark, which added considerably to its effect, and the appearance continued unchanged for about a quarter of an hour; but on a slight breeze springing up, small rays shot occasionally to the zenith, and the arch became agitated with a gentle and undulating motion, after which it spread irregularly, and, separating into the usual streamers, soon diffused itself over the whole sky. In stormy weather, the northern lights fly with the rapidity of lightning, and with a corresponding wildness to the gale which is blowing, giving an indescribable air of magic to the whole scene. I have never contemplated the aurora without experiencing the most awful sensations, and can readily excuse the poor untutored Indians for supposing that in the rest-

less motions of the northern lights they behold the spirits of their fathers roaming in freedom through the land of souls."

Thus have we collected together a few out of the vast number of facts which illustrate the nature of Thunder-storms, and the general electrical conditions of the air; showing how completely we are surrounded at all times by an astonishing and mysterious agency, which, in the hand of the Almighty, is either silently at work producing the most beneficial effects on the earth and atmosphere, or it is raised powerfully and audibly to bespeak His Majesty, and to do His will.

> "The thunder rolls: be hush'd the prostrate world:
> While cloud to cloud returns the solemn hymn.
> Bleat out afresh, ye hills: ye mossy rocks,
> Retain the sound: the broad responsive low,
> Ye valleys, raise; for the Great Shepherd reigns;
> And his unsuffering kingdom yet will come."

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